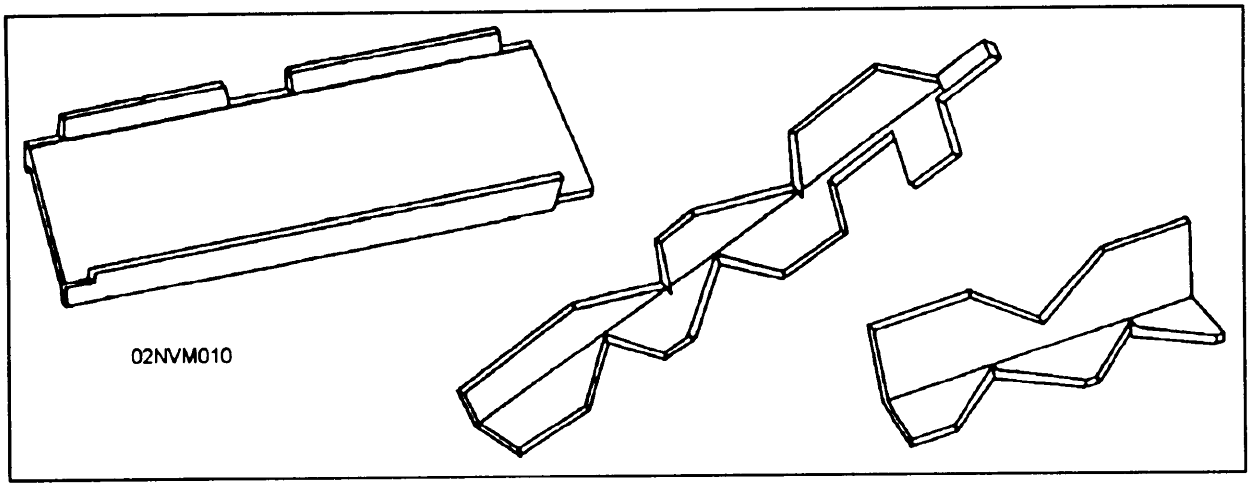
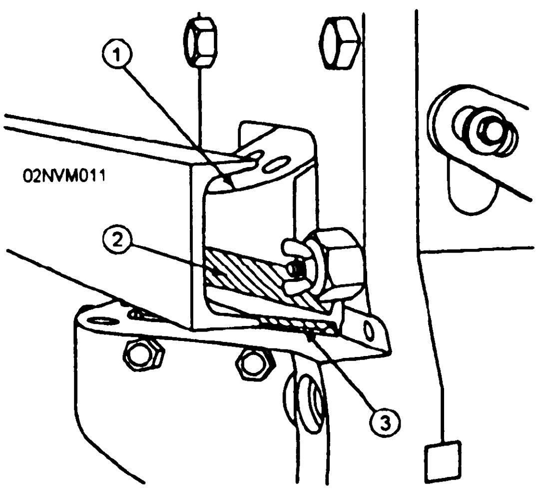
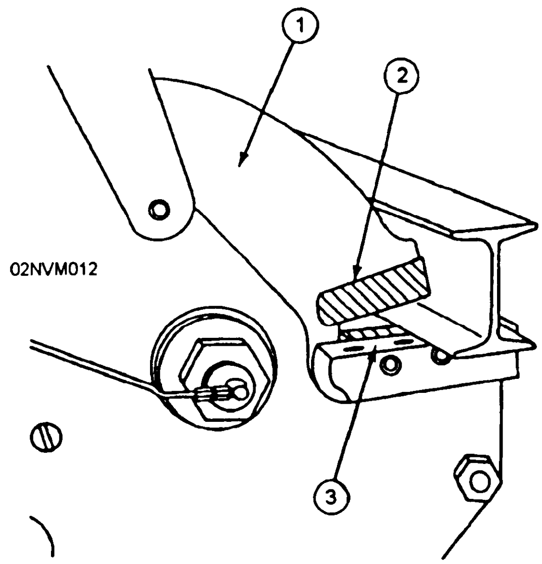


Figure 13-30.—Typical notcher and coper work.



1. Punch Holder
2. Notcher Puncher
3. Die Holder

Figure 13-31.—Universal ironworker notcher punch.



1. Punch Holder
2. Coper Punch
3. Die Holder

Figure 13-32.—Universal ironworker coper punch.

knives are firmly fastened since they have a tendency to work loose during use.

2. Cycle the machine through one complete revolution, checking the machine for binding or misalignment.

3. Place the workpiece between the cutting knives and adjust the holddowns, if installed, to support the material being cut and to prevent kickback.

4. Ensure that the material to be cut is supported on two sides of the die to prevent kickup and rolling during the cutting evolution.

5. Step on the foot pedal and hold the pressure until the knives have cut the workpiece.

Pullmax

The Pullmax machine is one of the most important timesaving machines in the shipfitter shop. It is also one of the most underutilized machines in the shipfitter shop. It is capable of shearing, nibbling, slot-cutting, beading, edge-bending, dishing, and numerous other operations depending on setup and tooling. The Pullmax is being included in this section on cutting metals since that is its primary function in the shipfitter shop. For the purpose of this training manual, we will only discuss the shearing capabilities of the machine. If you want to become more familiar with the capabilities of this machine, you should study the operator's manual and practice on the machine in your shop, if it has one installed.

PULLMAX SAFETY.—The Pullmax is a relatively simple machine to operate and does not present any special safety requirements. However, you need to ensure that the tooling is installed correctly. The machine cuts using a reciprocating action that causes abnormal vibration in the workpiece. Therefore, do not operate the machine for extended periods of time without taking a break from machine operations. You can seriously damage your hands and arms by exposing them to continuous vibration.

GENERAL SPECIFICATIONS.—Most shipfitter shops are equipped with machines capable of cutting plate up to 3/8 inch thick, as shown in figure 13-33. As in all machines, the thickness capacity is given for mild steel. If using alloy steel, the thickness capacity will be reduced. The cutting and shaping action is provided by tools mounted in tool holders at the front of the machine. The machine has two speeds of operation: slow and fast.

When the motor is running at slow speed, the cutting tool makes 500 to 1,000 strokes per minute. Slow speed is used to cut heavy gauge metal.

When the motor is running at high speed, the cutting tool makes 1,000 to 2,000 strokes per minute. High speed is used to cut thin gauge metal.

PULLMAX OPERATIONS.—The Pullmax has the capacity to perform many specific operations depending on the tools (blades) installed in the machine. Figures 13-35 and 13-36 show two of several different tools made for the Pullmax. We will be discussing the tools used for shearing (cutting) (fig. 13-34).

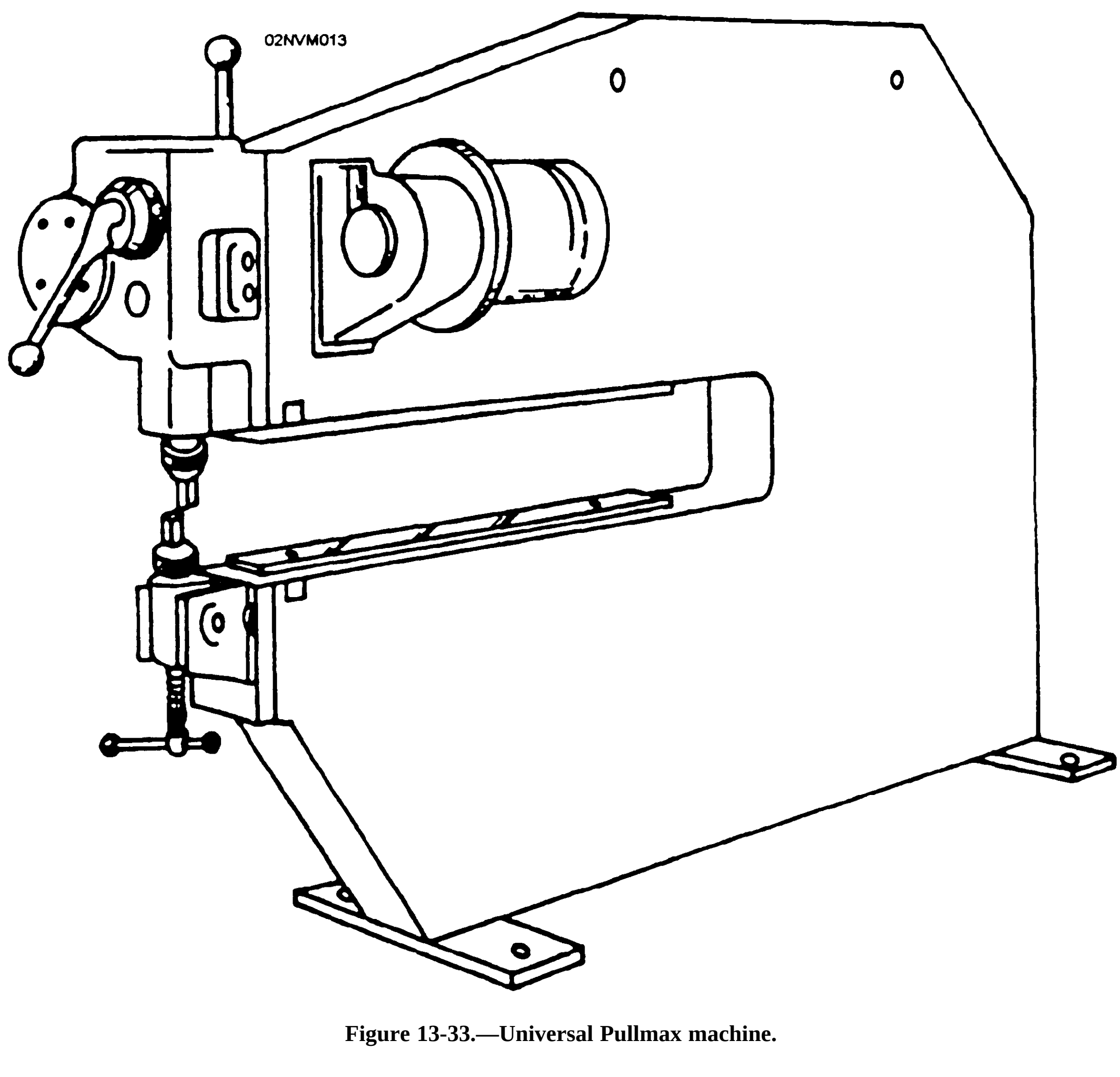


Figure 13-33.—Universal Pullmax machine.

Tooling Setup.—Select the proper tooling for the task assigned. For cutting straight and circular lines, use shearing tools, as shown in figure 13-36. Shearing tools may be used for cutting a freehand pattern or for contouring the inside or outside perimeter of a project. Tooling setup steps are as follows:

1. Select the proper tooling and install them in the proper tool holder. Hand tighten the tightening nut. Figure 13-36 shows the proper positioning of the tools.

2. Lower the upper tool into the cutting position by using the lever on the front of the machine, as shown in figure 13-36.

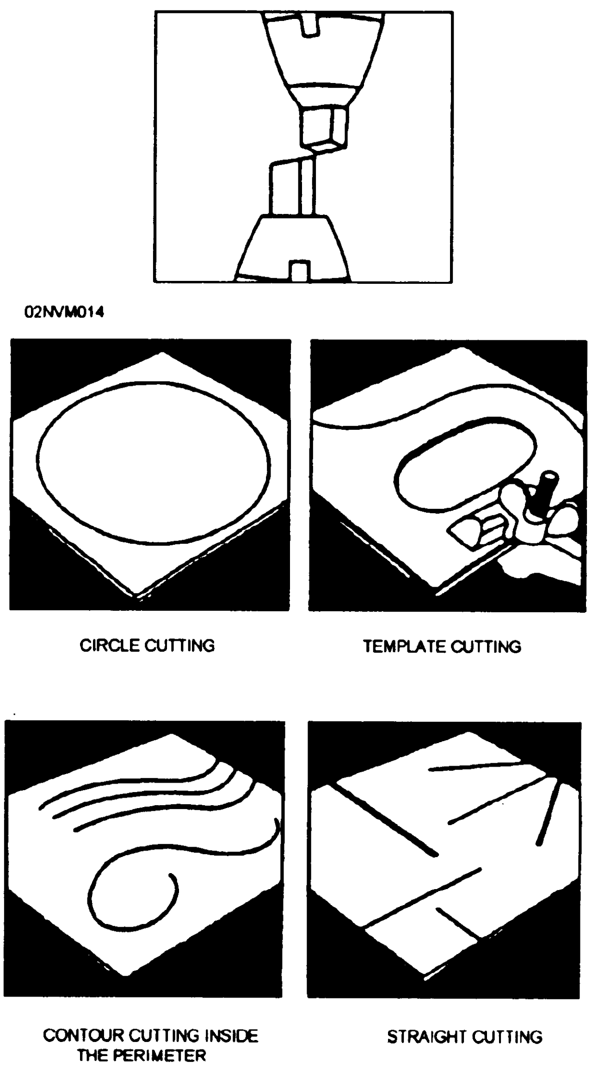


Figure 13-34.—Shearing tools.

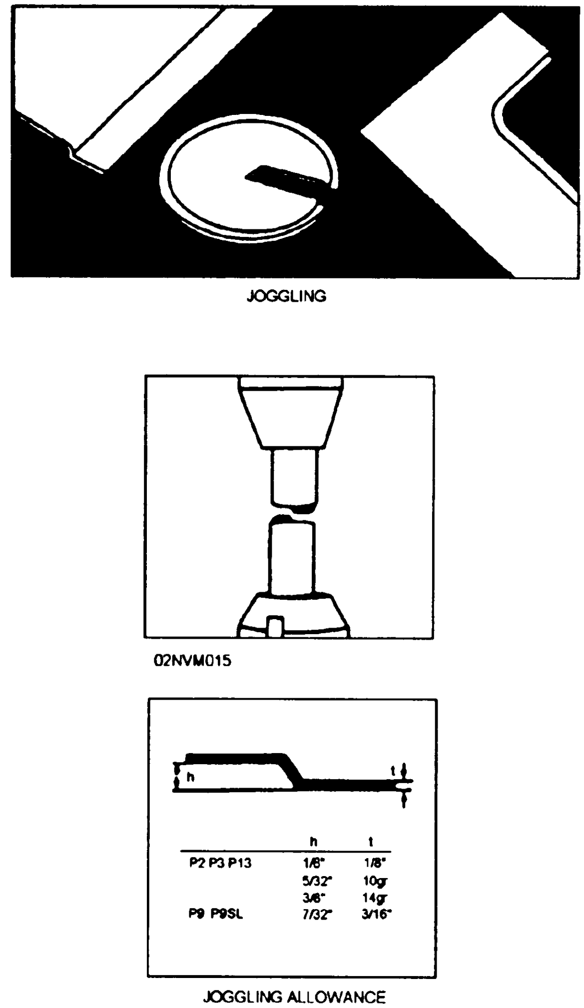


Figure 13-35.—Joggling tools.

3. With the tools in the cutting position, check the clearance between the upper and lower tooling. Use a piece of white paper as a background to check for side clearance. Look from one side directly at the white paper background. You should have a clearance of 0.002 to 0.003 inch. An improper clearance adjustment will result in a poor quality cut or damage to the machine.

4. Adjust the tool for side clearance by turning the side adjustment screw located on the left-hand side of the toolholder, as shown in figure 13-36. Turning the adjustment screw clockwise will close the clearance; while turning it counterclockwise will open the clearance between the tools.

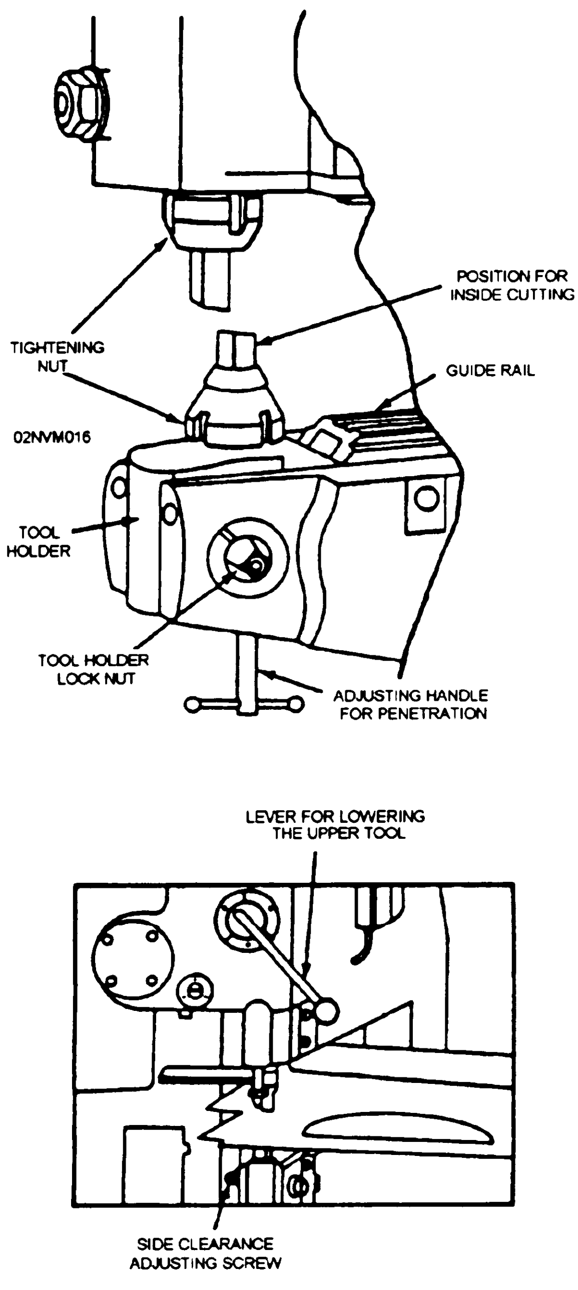


Figure 13-36.—Pullmax universal machine, upper and lower cutting tools.

5. When the adjustment is correct, tighten the toolholder locknut opposite the adjusting screw.

6. Make adjustments for proper penetration with the tools in the cutting position. Use the adjusting handle at the bottom of the toolholder to adjust the lower tool so that it will only penetrate 1/3 of the thickness being cut.

7. Cycle the machine, checking the machine for binding or misalignment.

8. Make a test cut on a sample of the metal being cut.

Stroke and Speed Control.—The stroke and speed of the upper tool is important if a smooth cut is to be obtained. We have already discussed speed control earlier. You should remember that high speed is used to cut thin metal and slow speed is used to cut thicker gauge metal Stroke control is obtained by using the same lever that lowers the upper tool into the cutting position. When the lever is engaged to the left, you will get a short stroke. A short stroke is used to cut thin metal. When the lever is engaged to the right, you will get a long stroke, which is used to cut thin metal.

Plasma Arc Machine

Plasma arc cutting is a high-speed, high-quality metal cutting process that greatly reduces cutting and edge preparation costs. Plasma arc cutting is similar to tungsten inert gas welding because it uses the same basic circuit and shielding gas. The plasma arc cutting torch greatly reduces cutting time and replaces slower machinery previously used to accomplish the same task. The cutting process uses extremely high temperatures, high-velocity ions, and a constricted arc between a tungsten electrode and the piece to be cut. This section will describe the procedures for using a typical thermal arc cutting system with water cooling at 300 amperes.

PLASMA ARC CUTTING SAFETY.—Plasma arc cutting requires the same personal protection equipment that is required for arc welding. Plasma arc cutting produces toxic gases from the cutting process. It also produces hot sparks and sound levels above 105 decibels. It uses higher temperatures than arc welding. You should never use solvents and degreasers of the halogen family near the cutting operation, because light from the arc can break these down into toxic components. The halogen family includes any of the nonmetallic elements, such as fluorine, chlorine, iodine, bromine, and astatine.

PLASMA ARC EQUIPMENT.—The equipment used for plasma arc cutting is similar to a gas tungsten arc welding (GTAW) unit. The plasma arc cutting unit has four basic components: the control panel, torch, torch leads, and gas supply. Figure 13-37 shows a typical setup for the control panel and torch.

Control Panel and Power Source.—The control panel is the operating station for the machine. It controls the power supply to the torch. The power supply is a 200-volt, open-circuit, dc power source with a drooping volt/ampere characteristic. It also provides a pilot power supply of less than 200 volts, dc, open circuit for the operation of the pilot arc to start the arc cutting process. A typical control panel will have a gas flowmeter, ammeter, fuse panel, gas mixing control panel, and amperage setting dial.

Plasma Arc Torch.—The torch body is composed of a handle, a ceramic cup, and a tungsten electrode. The handle is similar to a GTAW torch and serves as an attachment base for the ceramic cup and as an electrode holder. The ceramic cup concentrates and columnates the energy of the arc stream created inside the torch. The electrode provides the electrical current required to produce the ionized plasma gas. The electrode should be replaced if it becomes eroded or out-of-round. Resharpen the electrode when the eroded part in the center becomes l/8 inch in diameter. Keep the following points in mind when sharpening electrodes:

- Sharpen the electrode with a 0.218-inch diameter, flat in the center, and a 60-degree included angle.
- The electrode must be concentric with the electrode outside diameter.
- A scribe line on the electrode body indicates the limit to which the electrode can be resharpened.

Torch Leads.—The plasma arc machine has four different color-coded torch leads and connections to supply plasma gas and cooling water to the torch. The four color-coded connections are as follows:

- Green for the negative water-cooled lead
- Red for the positive water-cooled lead
- Black for the plasma gas
- Yellow for the shield gas

CAUTION: Purge the gas hoses prior to use to remove any moisture that may have entered the torch or leads during storage, shipment, or setup.

Gas Mixture.—Gas mixtures for plasma arc cutting serves similar functions as those used for GTAW welding. A mixture of argon (AR) and hydrogen (H)

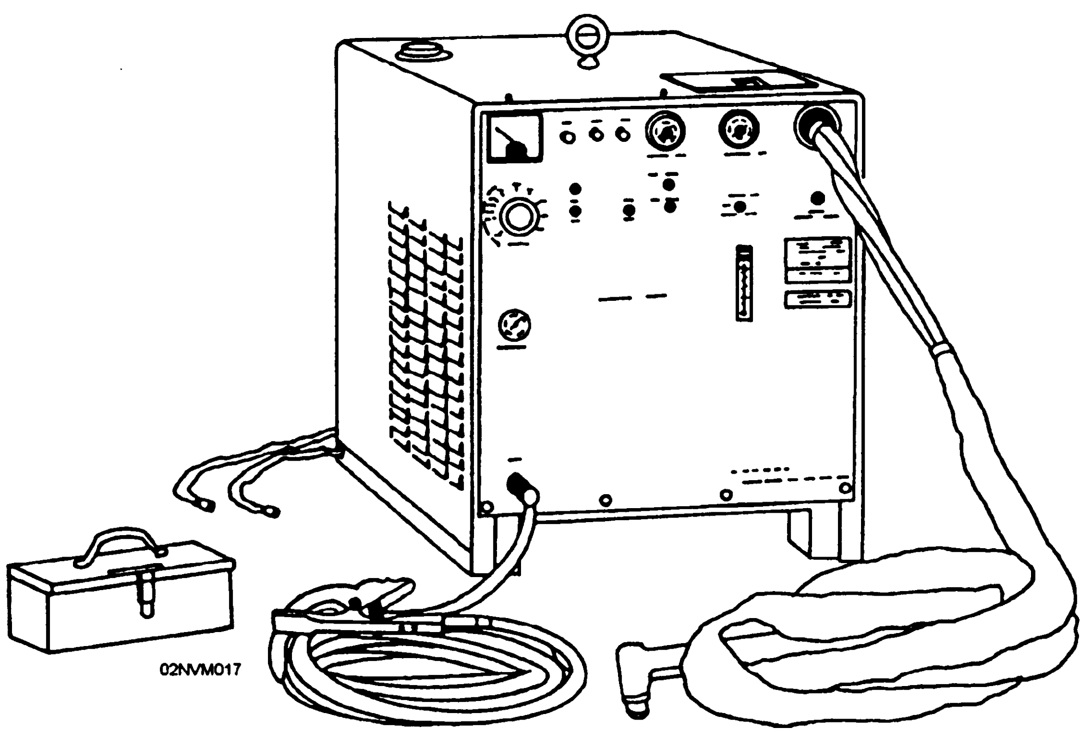


Figure 13-37.—Plasma arc cutting equipment.

gases are used for the plasma gas in cutting aluminum, and nitrogen(N) is used for other metals. The shielding gas used is carbon dioxide (CO_2). Table 13-4 shows the gas mixtures for automatic and manual cutting process.

PLASMA ARC CUTTING PROCESS.—The plasma arc cutting process employs extremely high temperatures, high-velocity ions, and a constricted arc between a tungsten electrode and the piece to be cut. This concentrated and columnated energy is produced by the electrode heating the plasma gas in the torch body to produce high-temperature ionized gas. This ionized gas is forced out of the torch through the ceramic cup, which concentrates and colmunates the energy. As the ionized gas strikes the plate, the metal is melted and the jet-like action of the arc removes the molten metal mechanically. The inert gas atmosphere prevents oxidation of the kerf wall.

Table 13-4.—Gas Mixtures for Plasma Arc Cutting Machines

Plasma Gas AR/H_2	40 psi	(Aluminum)
Plasma Gas N_2	20 - 40 psi	(All others)
Secondary Gas CO_2	40 psi	

FORMING MACHINERY

This section will take a look at machinery associated with forming metal plate and shapes, such as the sliproll forming machine, the brake press, and the Hossfeld Bender.

Sliproll Forming Machine

Sheet metal can be formed into curves over pipe or a mandrel, but steel plate requires machinery capable of providing considerably more pressure in the forming process. You have already been introduced to the sliproll forming machine in the chapter 12. The powered sliproll machine (fig. 13-38) used in the shipfitter shop operates on the same principle as the hand-powered sliproll used in the sheet metal shop. The powered sliproll machines found in the shipfitter shop are capable of rolling plate up to l/2 inch in thickness. Since steel plate is stiffer than sheet metal, you must take greater care when feeding the plate into the machine to ensure accurate rolling of the plate. Figure 13-39 shows some of the common problems associated with rolling plate.

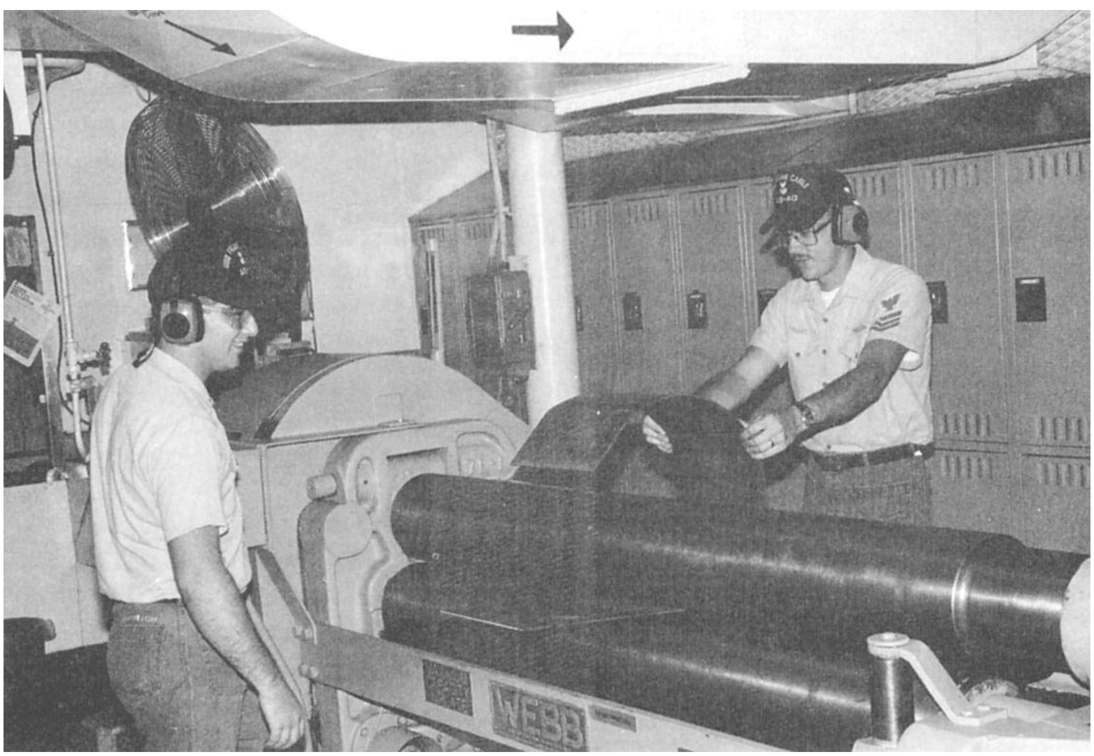


Figure 13-38.—Sliproll forming machine.

Press Brake

The power press brake is a large hydraulically driven machine that bends metal to desired angles using punches and dies. Most press brakes are rated at 300 tons of hydraulic bending pressure. They are capable of bending steel plate between l/8 to l/2 inch thick by 8 feet long to a 90-degree bend. These machines are generally used to bend plate steel to various degrees up to 90 degrees. Press brakes may also be used to bend cone and cylindrically shaped objects by making several smaller bends close together to roll the plate. In this section, we will look at the safety precautions,

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TROUBLE SHOOTING CHART

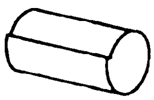
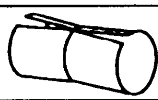
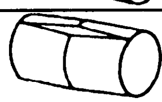
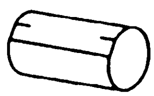
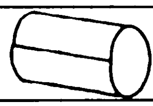
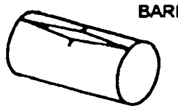
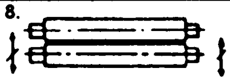
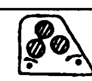
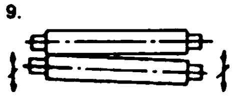
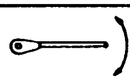
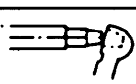
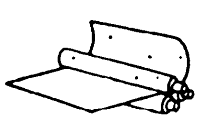
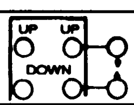
EXAMPLE	CAUSE	CORRECTION
1.  CYLINDER WILL NOT LINE UP SPIRALLING	A. SHEET DID NOT ENTER ROLLS STRAIGHT B. LOWER ROLLS NOT LEVEL C. SHEET IS NOT SQUARE	A. CHANGE ANGLE OF ENTRY B. CHECK WITH GAUGE, ALINE WITH CLUTCH, COUPLING, RATCHET WRENCH OR HAND WHEEL C. USE SQUARE SHEETS
2.  HOUR-GLASSING	LIGHT MATERIAL TOO TIGHT SETTING ON PINCH ROLL	CHANGE SETTING OF PINCH ROLL
3.  BARRELLING	OVERLOAD	CHECK CAPACITY CHART
4.  FLAT SPOT	EDGE NOT PREFORMED	PREFORM ON BACK SIDE OF MACHINE THEN ENTER PREFORM EDGE IN FRONT SIDE PREFORM ON PRESS BRAKE PRIOR TO ROLLING
5.  CYLINDER IS NOT CONCEN-TRIC	ROLLS MAY BE BENT	CHECK WITH INDICATOR, STRAIGHTEN
6.  BARRELLING AT JOINT ONLY LEADING OR TAILING EDGES BODY OF CYLINDER TRUE	OVERLOAD OR PINCH ROLLS SET TOO TIGHT	CHANGE SETTING ON PINCH ROLL
7.  ALL ROLLS NOT ROTATING	DRIVE CLUTCH SLIPPING	ADJUST CLUTCH
8.  ROLLS LOCKED IN POSITION	ROLLS JAMMED	MANUALLY ROTATE CONNECTING SHAFT  TO LOWER
9.  ONE END OF LOWER ROLL WILL NOT MOVE	A. CHECK SHEAR PIN IN RAISING SCREW HEAD B. CHECK WORM GEAR C. CHECK COUPLING & CLUTCH ON CONNECTING SHAFT	REPLACE
10.  RATCHET WRENCH FAILS TO LOWER ROLL	NEW MACHINE NOT BROKEN IN	TURN ON MAIN DRIVE AND WHILE THE ROLLS ARE TURNING USE RATCHET WRENCH
11.  TOP ROLL WILL NOT ENTER TAIL HINGE	PULL ROD OUT OF ADJUSTMENT	TO RAISE TOP ROLL TIGHTEN PULL ROD TO LOWER TOP ROLL LOOSEN PULL ROD
12.  MARRING MARRING DOES NOT EFFECT THE ROLLING OPERATION	A. MARRING OF ROLLS MAY TAKE PLACE ON NEW MACHINE UNTIL THE ROLLS WORK HARDEN B. MARRING MAY BE CAUSED BY FRAME CUT EDGES ON PLATE SLIPPING DRIVE CLUTCH C. SEE FIGURE 7. D. METAL BUILD UP ON ROLL SURFACES	A. AFTER ROLLING FIRST FEW SHEETS THE ROLLS WILL BECOME WORK HARDENED AND MARRING SHOULD CEASE B. FLAME CUT EDGES SHOULD BE GROUND C. TIGHTEN CLUTCH D. GRIND OR EMERY OFF
13.  LOWER ROLLS TRAVEL IN WRONG DIRECTION THAN INDICATED ON CONTROL PANEL	WIRED WRONG	REVERSE TWO POWER LEADS

Figure 13-39.—Sliproll forming machine troubleshooting chart.

setup, and operation of a typical brake press. Figure 13-40 shows a typical brake press.

BRAKE PRESS SAFETY.—The brake press is capable of operating at hydraulic pressures of up to 300 tons. Due to these high pressures and the machine operating capacity, there are several important safety precautions you should follow. They are as follows:

—Become familiar with the type of brake press installed in your shop. Qualify on its use and operation under qualified supervision prior to operating the brake press.

—Determine the capacity of the machine being used from the manufacturer's technical manual and NEVER exceed its maximum capacity. Capacities for most machines are given in metal thickness, length, and, unless otherwise noted, are given for mild steel not alloy steels.

—Never place any part of your body under the dies and punches of the press brake.

—Never place hands or fingers between the metal plate and the die.

—Never, never have your foot on the trip lever or foot pedal while loading or adjusting plate on the brake.

—Never attempt to bend pipe, bar stock, round stock, flat bar less than 2 inches in width, or other similar metal shapes. If you attempt to bend these types of metal shapes, you will damage the dies and risk injury.

BRAKE PRESS SETUP.—When you set up the brake press, there are three important setup adjustments to make. You must select the proper set of dies, bending pressure, and machine stroke. We will look at the requirements for each of these adjustments.

Die Selection.—The brake press is capable of using different dies to perform several different functions. The top half of the die is called the punch and the lower half is called the die. The "V" die is the most common punch and die combination used in the shipfitter shop. These dies allow plate to be bent at various angles. When selecting the opening for the "V" die, it should equal eight times the thickness of plate being bent. You will find a single "V" die with four openings in most shipfitter shops for bending l/8-, l/4-, 3/8-, and

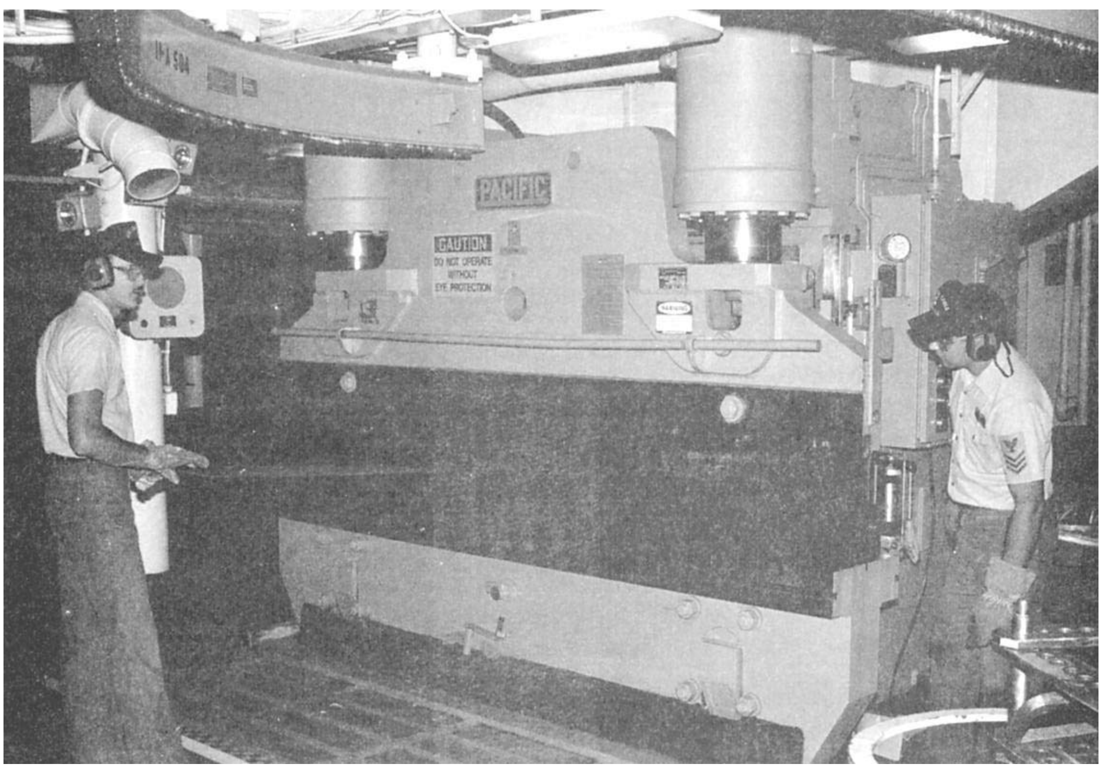


Figure 13-40.—Brake press.

l/2-inch plate (fig. 13-41). This die is simply rotated to the correct opening for the task at hand.

Bending Pressure.—Bending pressures on brake presses are set to the correct pressure to allow for the proper bending of the desired material to be bent. Too low of a pressure setting will cause incomplete bending of the plate. If the bending pressure is set too high, the metal may be forced too far into the dies, causing marring of the surface and overbending of the plate. Due to the number of different machines in use, we will not cover the actual setting of hydraulic pressure. You should refer to the owner's technical manual for proper bending pressure and pressure adjustment.

Stroke Setting.—Stroke setting is how far the ram will travel in one cycle of the ram. You will choose the type of stroke to use depending on the job at hand and the experience of the operator. The machine in your shop may have stroke selector switches with different labels but will perform the same basic functions. The four choices of the stroke are as follows:

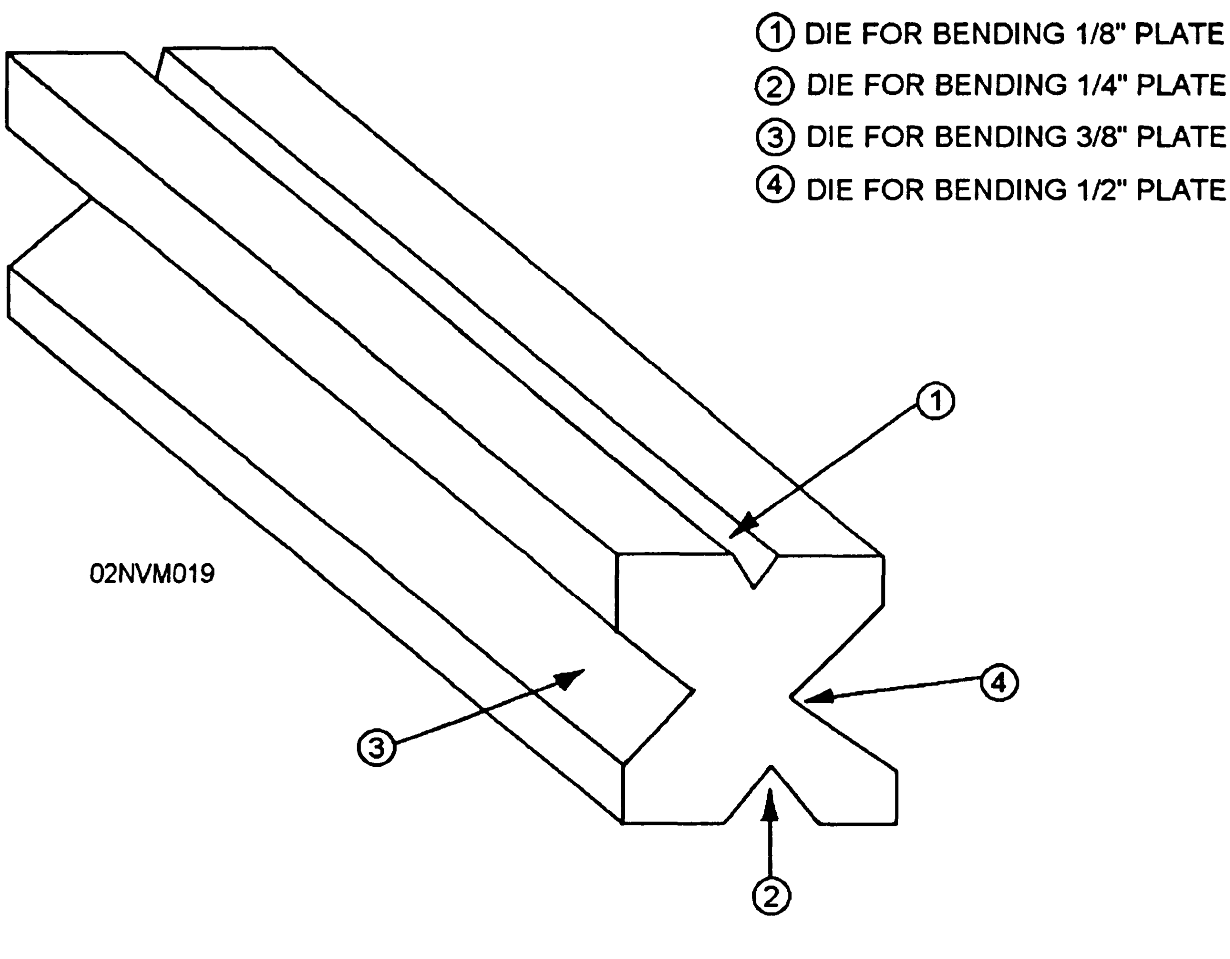


Figure 13-41.—Typical "V" die.

- CONTINUOUS—The press will run continuously until the stop button is pushed.

- INCH—The ram may be inched by use of any selected button or foot switch and will stop whenever the button is released, regardless of the stroke position.

- LONG—The operator holds the run button or foot switch until the ram reaches the bottom of the stroke. When the run button or foot switch is released, the ram automatically returns to the top of the stroke and stops.

- SHORT—A single momentary operation of buttons or foot switches will cause the ram to go through one complete cycle.

The total travel of the ram is controlled by the setting limit switches. Limit switches are installed to provide an accurate range of travel for the ram so that the same bend may be made time after time without resetting the machine. There are several types of limit switches used depending on the type of machine. Some machines use set screws, depth gauges, pressure switches, micrometer adjustments, or a combination of several different types. The use of a depth gauge and micrometer are the most accurate, since you can make adjustments in one-thousandths of an inch.

PRESS BRAKE OPERATIONS.—After setting up and making all necessary adjustments to the machine, you are ready to make bends with the press brake. The following is a list of the procedures to follow when operating the press brake:

- Select and position the proper dies.

- Check the ram to ensure that the ram is parallel to the bed. Make adjustments, if necessary. Some presses are capable of working with the ram tilted so that you can bend items, like funnels, where you would want a tighter bend in the throat than at the edge. For most work, you will want the ram parallel to the bed.

- Set the depth of the ram stroke and check the setting on a scrap piece of metal.

- Load the plate in the machine. Work in the center of the press, where possible. If it is necessary to make heavy bends at one end of the machine, place a dummy load at the opposite end of the machine.

- Ensure that the plate is aligned for proper location of bend. Place hands under the plate. Be sure the head and upper body are clear from the plate. Do not lean over the work while bending the plate.

- Engage the ram by activating the foot switch or hand buttons.

Hossfeld Bender

The Hossfeld Bender is used to bend radii and angles on a wide variety of shapes including small rods, piping, tubing, flat stock, and angle iron. The Hossfeld Bender is available in two models. Model No. 1 is a manually operated machine. Model No. 2 is a larger hydraulically operated machine. Due to the numerous attachments and arrangement of these attachments on the frame of the bender, we will only discuss the components of the machine, die selection, and the capacity of the machine. To properly set up the machine, refer to the manufacturer's technical manual.

HOSSFELD BENDER COMPONENTS.—The Hossfeld Bender consists of two frames, a stop gauge, and a center pin. The component parts of the Hossfeld Bender are shown in figure 13-42 and are as follows:

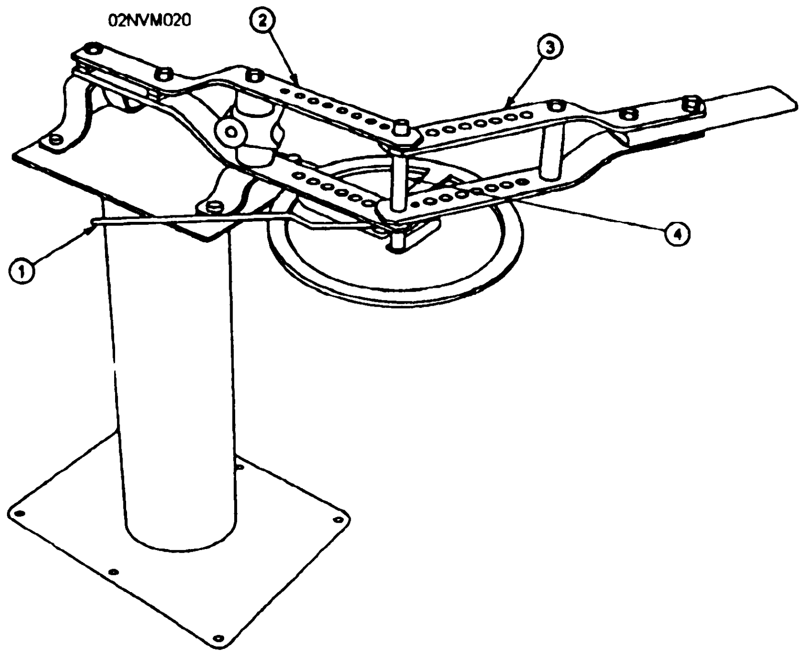
- MAIN FRAME—Stationary frame to which dies are attached. Each hole in the frame is labeled for proper die installation.

- SWINGING FRAME—Movable frame to which dies are attached. Each hole in the swinginig frame is labeled for proper die installation.

- ADJUSTABLE STOP GAUGE—Used as a guide for stopping the swinging frame when producing quantities of identical parts.

- CENTER PIN—Joins the main frame to the swinging frame. Used to mount dies.

DIE SELECTION.—Die selection is the most important consideration when setting up the Hossfeld Bender for use. You must follow the manufacturer's



1. Adjustable Stop Gauge
2. Main Frame
3. Swinging Frame
4. Center Pin

Figure 13-42.—Hossfeld Bender.

technical manual when setting the proper dies for the task at hand. Each die will be labeled with a number/letter combination to identify its use. An example of a die is 13B4, which is a grooved pipe bending die 2 inches in diameter. The dies are mounted on the frames at predetermined holes by pins. As with the dies, the holes in the frame and pins are also labeled so that you will position the dies in the correct position. Figure 13-43 shows the standard parts and dies used with the Hossfeld Bender.

Hossfeld Bender Capacities.—The Hossfeld Bender is used to bend pipe or tubing up to 2 inches in diameter, flat stock up to l/2 by 4 l/2 inches, 1 l/4-inch round or square stock, and 2-inch by 2-inch by 3/l6-inch angle iron.

FABRICATION

The fabrication of new items in the shop or on the job site will be your primary concern as a shipfitter. You will often work off of blueprints to manufacture parts to specifications. At other times, you will be manufacturing parts from preexisting parts and will be required to make targets or templates to work from. For you to function effectively in the shop, you need to have an understanding of the use of templates, targets, and erection aids, and the procedure used to figure bend allowances.

LIFTING TEMPLATES

A good deal of the plate work can be done by using lifting templates instead of actually developing patterns. Templates for plate work are commonly made from cardboard, heavy rosin paper, or template wood. Cardboard or paper are normally used for small parts and wood for larger sections. However, rosin paper can be used to make a lift template of a plate that has practically no curvature. Clear white pine in varying lengths, widths, and thicknesses is normally used as template wood. This material is soft and can be easily cut with a jackknife.

To lift a template, you need to get the size and shape of the piece, along with the size and location of all rivet holes or other special features, directly from the frames, stringers, plates, and other structures and around the repair area. To obtain the template, temporarily attach the template material to the particular piece that the template is to be lifted from. Then transfer an outline of the piece to the template material. You will normally

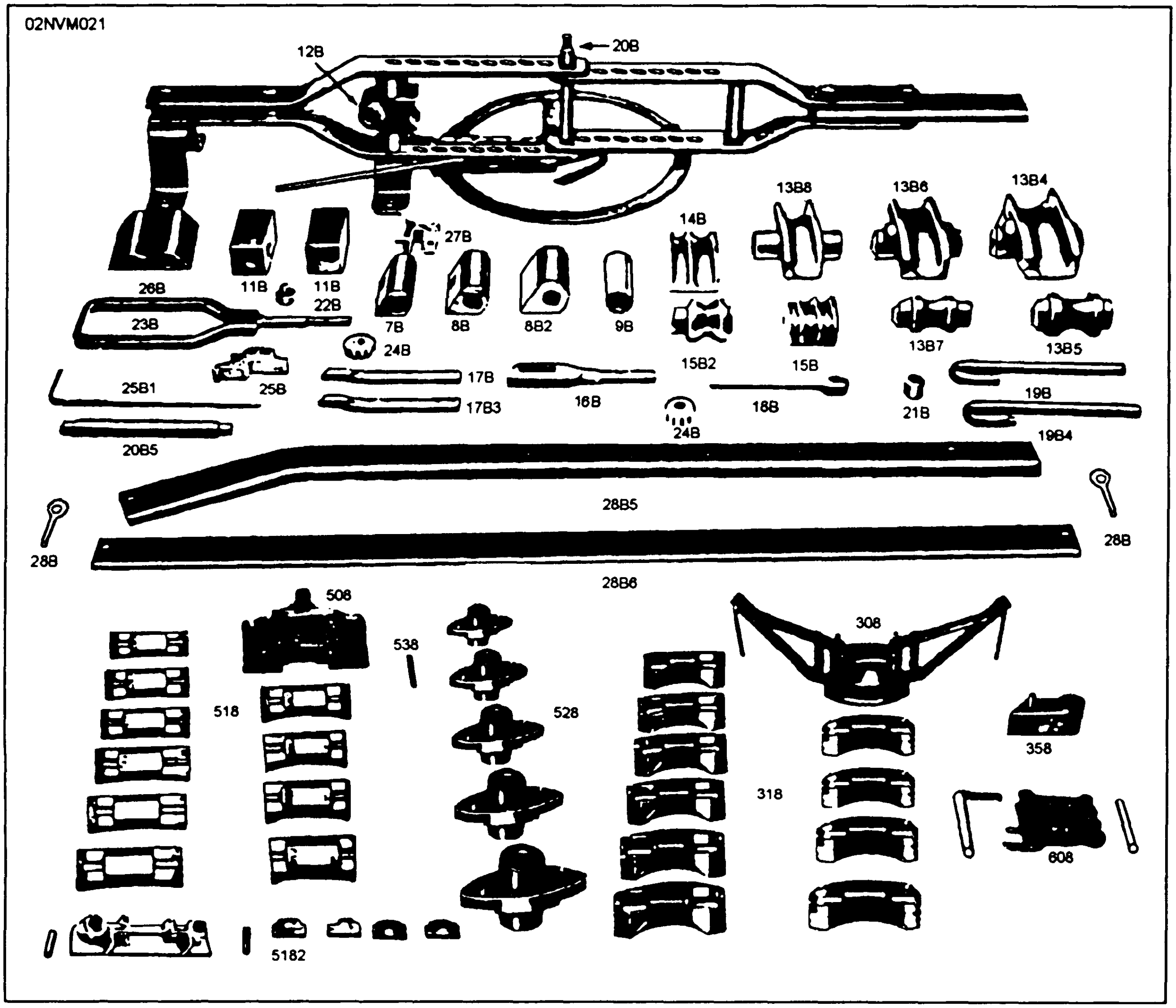


Figure 13-43.—Standard parts and dies.

have to cut and trim the template until you get the proper fit. Figure 13-44 demonstrates some of the more common uses for templates.

If the piece has a marked curvature, you will also need to make a SET (or gauge) to use as a guide while you roll the new part to the correct shape.

SET

A set is merely a narrow bar or strip of soft iron bent to the required curvature. The set is made of material that is the same thickness as the plate to be used. If the curvature is complex, more than one set will be required. Once the lift template and necessary sets are made, the new plate can be laid out. A lift template and set for a shell plate are shown in figure 13-45.

TARGETS

As a shipfitter, you will need to build targets from time to time when you manufacture numerous identical items or make repairs to structures that have numerous attachments that must be removed. You may also build a target to maintain certain dimensions or tolerances. Targets will be discussed in greater detail in the chapter on pipefitting and repair (chapter 16) but has similar applications to the shipfitter as well.

ERECTION AIDS

You will find the erection aids, shown in figure 13-46, to be very useful in fitting plate to the curvature of structures where it is not feasible to use the power bending machines. Erection aids are also used to align

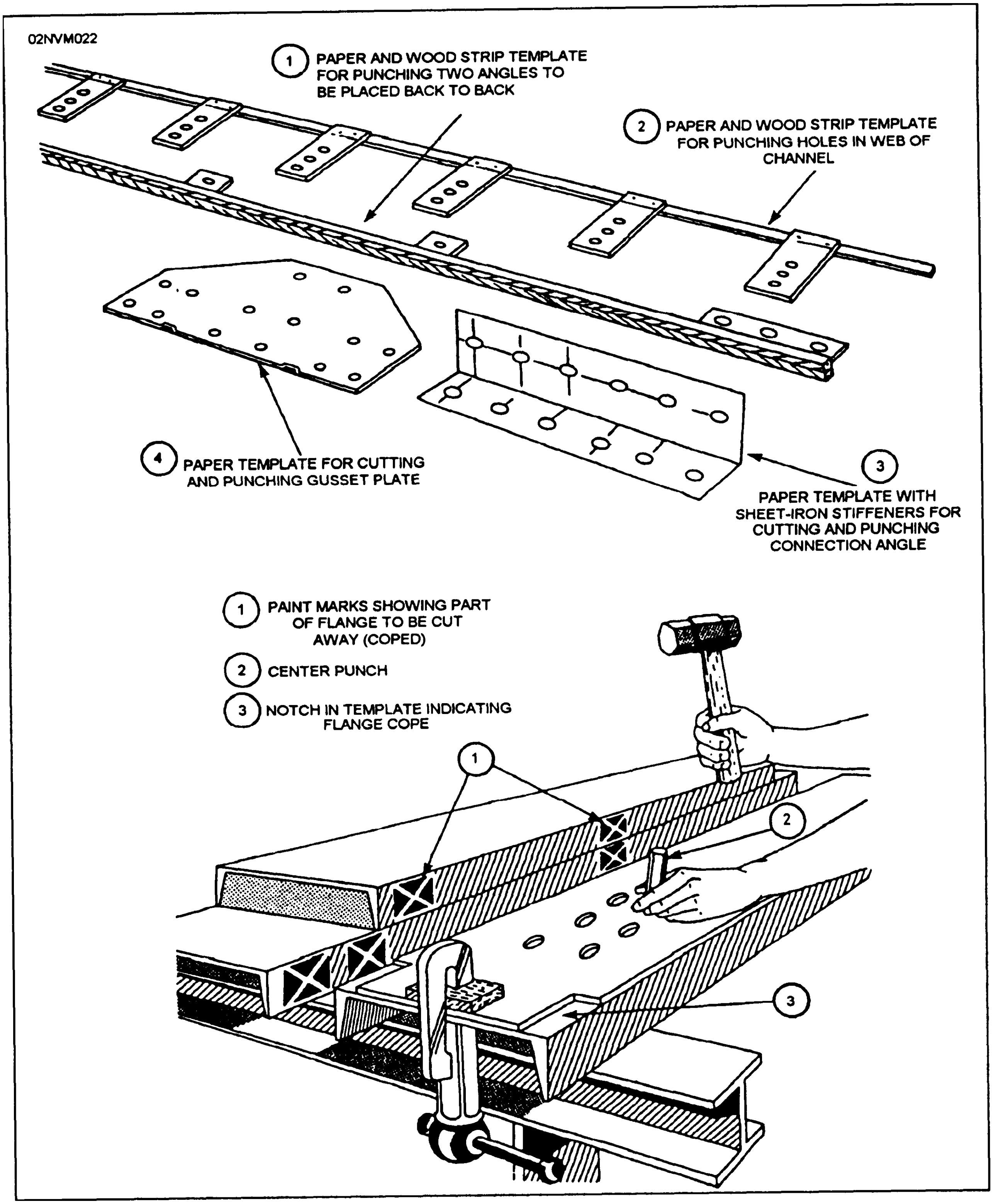


Figure 13-44.—Types of templates and their use.

and hold plate and structure in place while being joined. They are usually tack welded in place while being used. You should always install the erection aids so that they may be readily removed by striking the dog or clip with a hammer. Never fully weld an erection aid in place unless absolutely necessary. Figure 13-46 shows the correct way to use some of these aids.

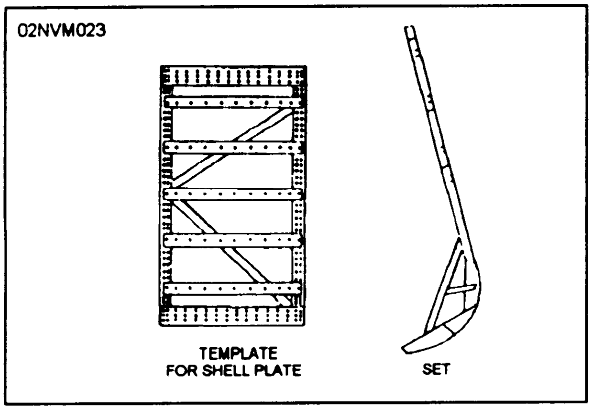


Figure 13-45.—Lifting template and set for shell plate.

BEND ALLOWANCE

Regardless of the method used to bend plate, you must always consider the thickness of the plate and provide an adequate bend allowance. The thicker the metal, the more important the calculation of the bend allowance. When working with thin sheet, you can estimate (or sometimes even disregard) the thickness of the material. If the thickness of the material in heavy plate is not considered, it will cause serious errors in specified dimensions, perhaps even a complete lack of fit between component parts.

When bending metal to exact dimensions, you must know the amount of material required to form the bend.

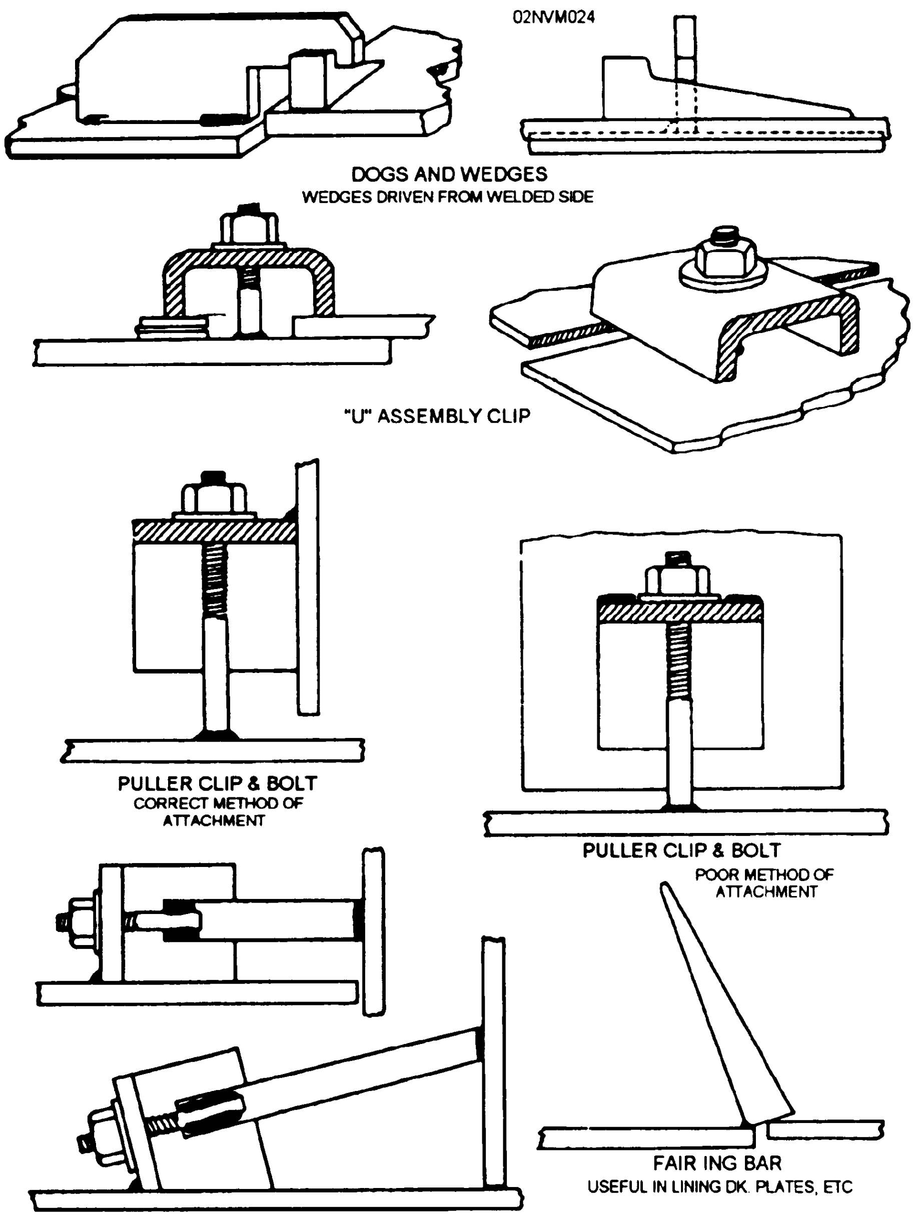


Figure 13-46.—Erection aids.

The amount of material required is known as the bend allowance.

In bending, the metal is compressed on the inside of the bend, and stretched on the outside of the bend. Halfway between these two surfaces or extremes is a space that neither shrinks nor stretches but retains the same length. This is known as the neutral axis. Figure 13-47 shows the neutral axis of a bend. The bend allowance is computed along this neutral axis.

Bend Allowance Terms

To understand the calculation and discussion of bend allowance, you need to be thoroughly familiar with the definitions used to calculate bend allowance. As you study the definitions, refer to figure 13-48 and locate each part described. Some parts are not shown in the figure but are described in the text. This section may be difficult to understand. You may need to go over it with a more experienced HT. The definitions are as follows:

LEG—The longer part of a formed angle.

FLANGE—The shorter part of a formed angle. If both parts are the same length, each is known as a leg.

MOLD LINE (ML)—The line formed by extending the outside surfaces of the leg and flange so that they intersect.

BEND TANGENT LINE (BL)—The line at which the metal starts to bend.

BEND ALLOWANCE (BA)—The amount of material consumed in making the bend.

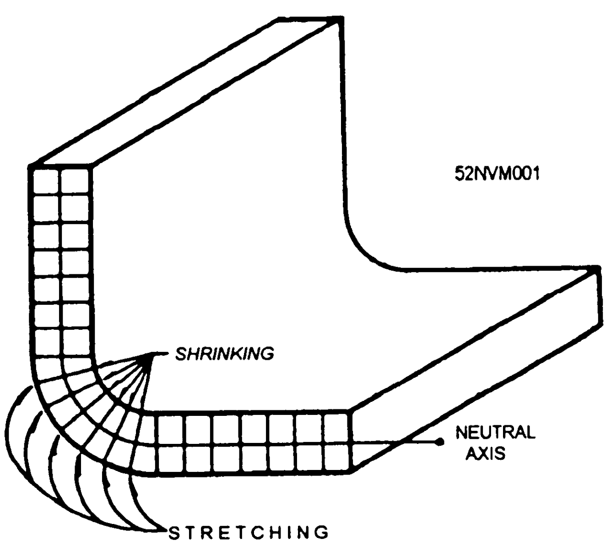


Figure 13-47.—Neutral axis.

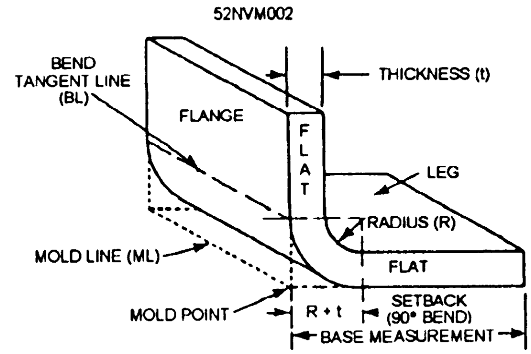


Figure 13-48.—Bend allowance terms.

RADIUS (R)—The radius of the bend. It is always measured from the inside of the bend unless otherwise stated.

SETBACK (SB)—The amount that the two mold line dimensions overlap when they are bent around the formed part. In a 90-degree bend, SB = R + t (radius of the bend plus thickness of the metal).

BEND LINE (also called brake or sight line)—The layout line on the metal being formed which is set even with the nose of the brake and serves as a guide in bending the work. (Before forming a bend, you must decide which end of the material can be most conveniently inserted in the brake.) The bend line is then measured and marked off with a soft pencil. Measure from the bend tangent line closest to the end that is to be placed under the brake. This measurement should be equal to the radius of the bend. The metal is then inserted in the brake so that the nose of the brake will fall directly over the bend line.

FLAT PORTION OR FLAT—The flat portion or flat of a plate is that portion that is not included in the bend. It is equal to the base measurements minus the setback.

BASE MEASUREMENT (or mold line measurement)—The base measurement is the outside dimensions of a formed plate. Base measurement will either be given on the blueprint or drawing, or it may be obtained from the original part.

CLOSED ANGLE—An angle that is less than 90° when measured between legs, or more than 90° when the amount of bend is measured.

OPEN ANGLE—An angle that is more than 90° when measured between legs, or less than 90° when the amount of bend is measured.

Computing Bend Allowance

To compute bend allowance, you must know two primary facts: the radius of the bend and the degree of angle in the bend. Usually, this information can be found on your blueprints or drawings.

As you study the following examples, refer to figure 13-49 to help you understand where and how the mathematical figures are obtained. Remember, bend allowance is measured from the inside of the bend but is computed along the neutral axis of the material being used. Therefore, when calculating bend allowance, add the bend radius to one-half of the thickness of the metal. This will determine the radius of the neutral axis.

Bend allowance is the product of the radius of the neutral axis of the bend which is multiplied by the size

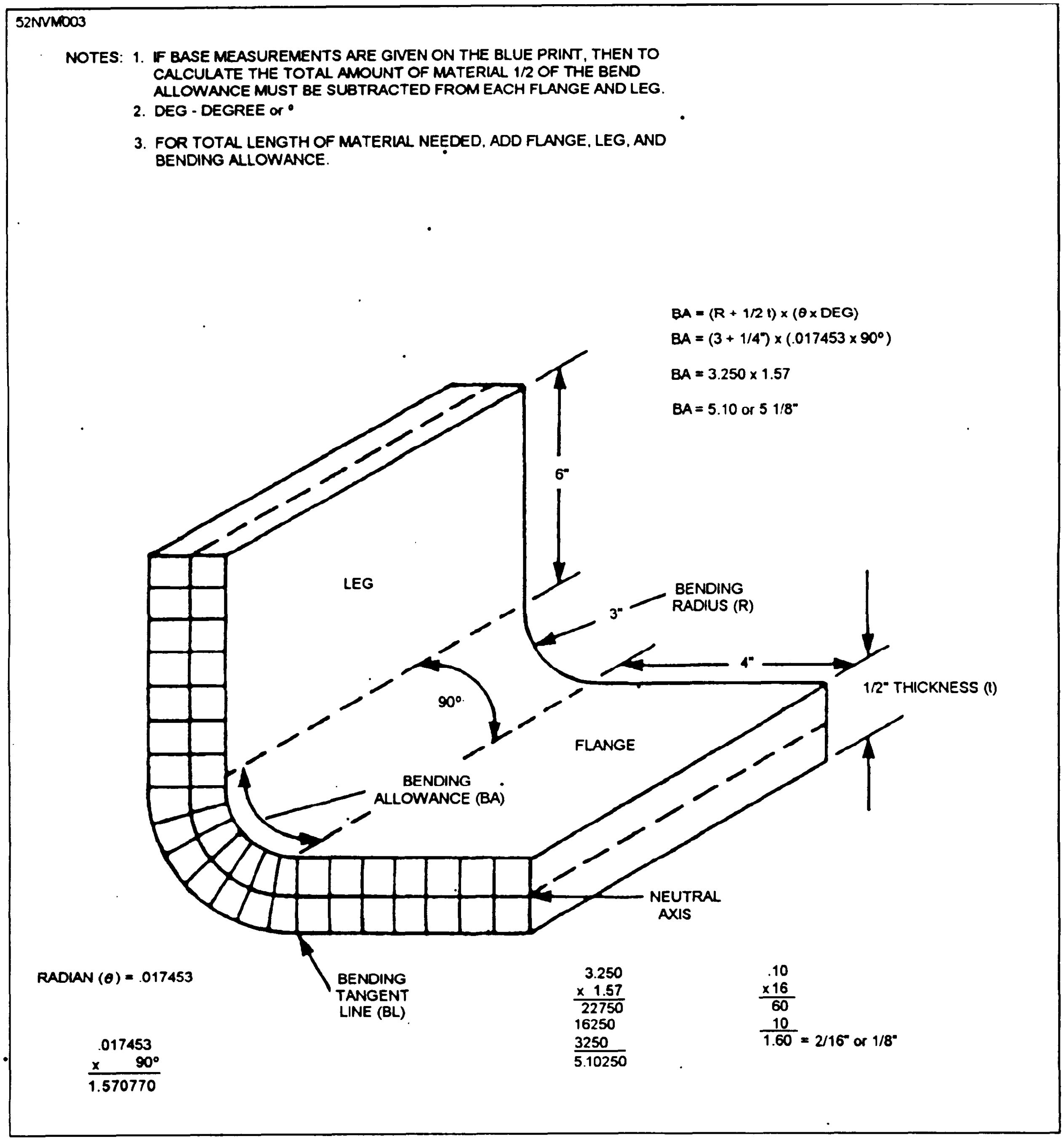


Figure 13-49.—Calculating bend allowance.

of the bend in radians. The radian relates the length of the arc generated to the size of the angle. For the purpose of computing bend allowance, the number of radians per degree of bend is 0.017453. Thus, the formula for bend allowance is:

$$ba = r \times R$$

Where:

ba = bend allowance

r= radius of the neutral axis of the bend

θ = size of the angle of the bend in radians

EXAMPLE 1 (fig. 13-49)—What is the bend allowance for a 90-degree bend with a 3-inch radius which is to be made in plate that is l/2 inch thick?

r = 3.00 + 0.250 = 3.250 inches.

(Remember you must add one-half the thickness of the plate to be bent to the radius of the bend.)

8 = 0.017453 x 90 = 1.57 radians

Therefore:

$$ba = 3.250 \times 1.57 = 5.10 \text{ inches}$$

EXAMPLE 2 (fig. 13-50)—What is the bend allowance for a 180-degree bend which is to be made in a length of l/2-inch stock?

r = 1.0 + 0.250 = 1.25 inches

$8 = 0.017453 \times 180 = 3.14$ radians

Therefore:

$$ba = 1.25 \times 3.14 = 3.925 \text{ inches}$$

REPAIRS AND FABRICATION

Much of your work will consist of repairs and alterations made to the existing ship's structures. Repairs are different from alterations in that the design of the ship’s structure is not changed by repairs.

For example, if you remove a deteriorated section of a watertight bulkhead and install a new section, it is

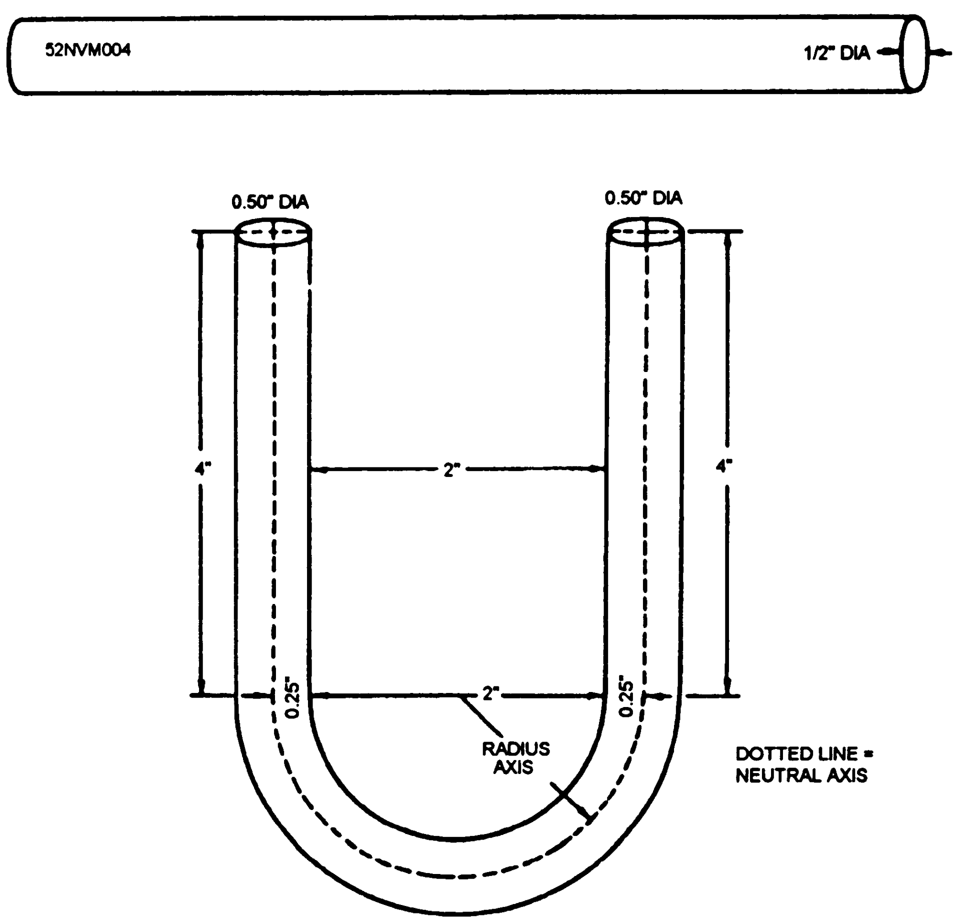


Figure 13-50.—Computing the overall length of a U-bolt.

considered a repair. However, if you cut a hole in a watertight bulkhead and install a watertight door that modifies the ship's structure, it is an alteration. All repairs and alterations must be performed according to the appropriate specifications and authorizations.

Some of the problems encountered when making repairs and alterations, such as avoiding notches in plate, cutting holes in plate, stopping cracks in plate, correcting distortion and other problems associated with plate, are discussed in the following paragraphs.

AVOIDING NOTCHES IN PLATE

When repairs and alterations are being made, you must take care to avoid introducing notches (geometrical discontinuities) in the ship's structure. These points of stress concentration form the starting points for fractures. Serious notches are often caused by striking arcs on plating adjacent to a weld or by leaving rough burned edges on the structure. Corners of doublers, insert plates, chips, and pads must lx rounded to eliminate the notch effect. Discontinuities, such as slag inclusions, incomplete fusion, and undercut in a weld, can also become the starting point for fractures. You must be careful in your workmanship and inspections to prevent the introduction of such notches into the structure.

HOLE REPAIRS

You will be called upon to make repairs to all types of holes in ship and submarine structures as well as equipment. A major source of hole repair is the repair of stripped out bolt holes in accesses and covers exposed to the weather. Generally, a hole must be 2 l/2 inches or less in diameter. Holes greater than 2 l/2 inches must be replaced with a patch. We will look at partial penetration holes and full penetration holes, as shown in figure 13-5 1.

Partial Penetration Holes

Partial penetration holes are those holes that do not extend through the base material more than three-fourths of the thickness of the plate, as shown in figure 13-51. Before welding up the hole, it must be opened up to a minimum of l/2 inch and a maximum of 2 l/2 inches at the bottom. The sides are tapered with a 20-degree minimum bevel to prevent slag entrapment and allow for rod manipulation. The hole is welded up using a filler metal compatible to the base material and the weld procedure being used.

Full Penetration Holes

Full penetration holes are those holes that extend through the base material, as shown in figure 13-51. Before welding up the hole, it must be opened up to a minimum of l/2 inch and a maximum of 2 l/2 inches at the bottom. The sides are tapered with a 20-degree minimum bevel to prevent slag entrapment and allow for rod manipulation.

The hole may be welded using a backing strap or left open. If a backing strap is used, it may be permanent or removable depending on the fabrication requirements. If a permanent backing strap is used, it must be of the same material as the base metal. If the removable backing strap is used, remove it by mechanical means such as a cutting torch or grinder. Most welders use a brass or copper backing strap clamped in place during the welding process. Since the brass backing strap will not fuse with the welding material, it will normally fall off with a light tap of a hammer. After the backing strap is removed the hole must be back gouged to 1/3T (where T equals material thickness) or 3/8 inch depth, whichever is less, and the back gouge is welded up. The reason for backgouging the repair is to remove impurities that are drawn into the weld metal from the brass plate. The hole is welded up using a filler metal compatible to the base material and the weld procedure being used.

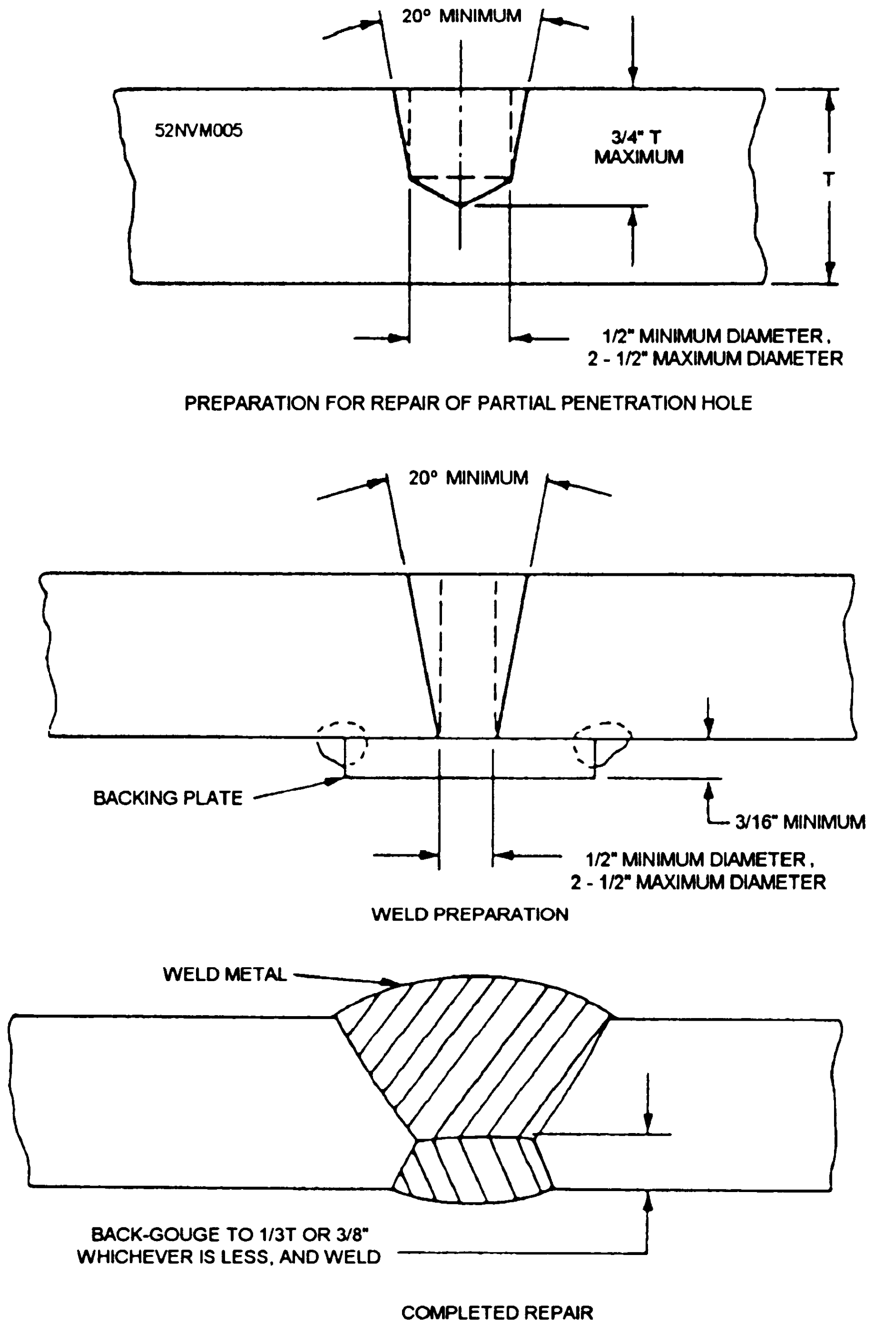
MAKING CLOSURES WITH PLATE PATCHES

Sometimes it is necessary to cut temporary holes in shell plating, bulkheads, and decks to remove and install machinery. You will have to measure, cut, and prepare the patch for insertion. All work must carefully be done so no unnecessary damage occurs. We will look at cutting new access holes and cutting access holes involving previously made holes.

Cutting New Access Holes

Cutting new access holes involves making cuts where no previously made cut existed. Before you make an access cut you must determine the location and configuration of the access cut. Figures 13-52 and 13-53 demonstrate some of the requirements for determining access cuts and weld preparations.

DETERMINING LOCATION.—Before making an access cut, you should consult the ship's plans for the



NOTES:

1. MULTIPLE PASSES SHALL BE USED WHEN MAKING REPAIR WELDS. REPAIR OF ORIGINAL HOLE DIAMETERS OVER 2-1/2 INCHES REQUIRES REPLACEMENT BY A 6-INCH OR 4T (WHICHEVER IS LARGER) MINIMUM DIAMETER PATCH ACCORDING TO MILSTD-1688, FABRICATION, WELDING, AND INSPECTION OF HY-80/100, SUBMARINE APPLICATIONS.
2. THIS FIGURE IS NOT DRAWN TO SCALE.

Figure 13-51.—Weld repair of partial and full penetration holes.

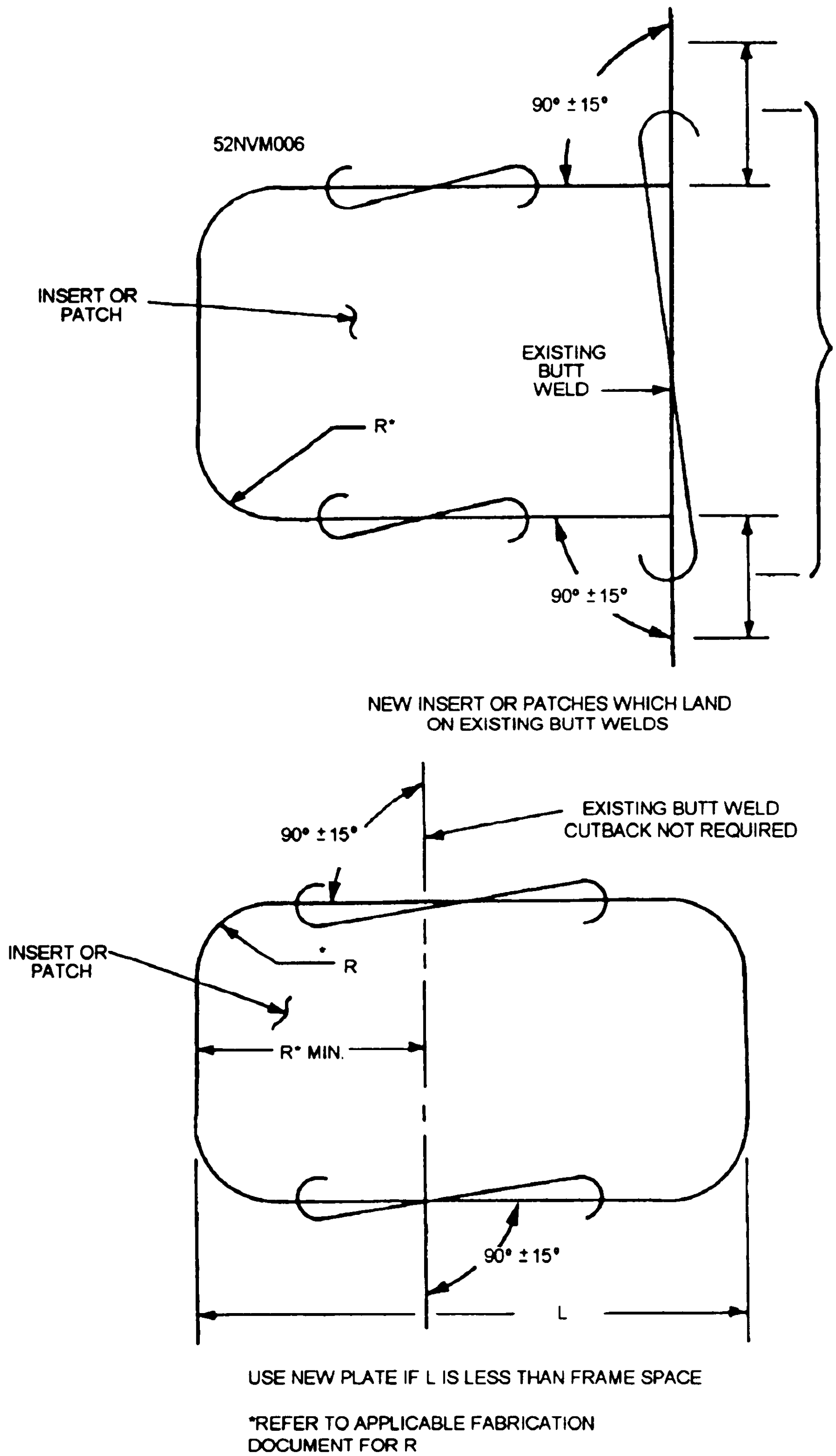


Figure 13-52.—New inserts or patches crossing existing butt welds.

location of access holes that may have been included in the ship's original construction. If the ship's plans include access areas for the removal of equipment, use these areas for your cut. If no access location is shown, use the following guidelines in determining a suitable area for a cut:

- Do not cut holes in the sheer stringer, keel, or bilge strakes unless necessary.

- Avoid cuts that will require rewelding closer than 6 inches from a riveted joint.

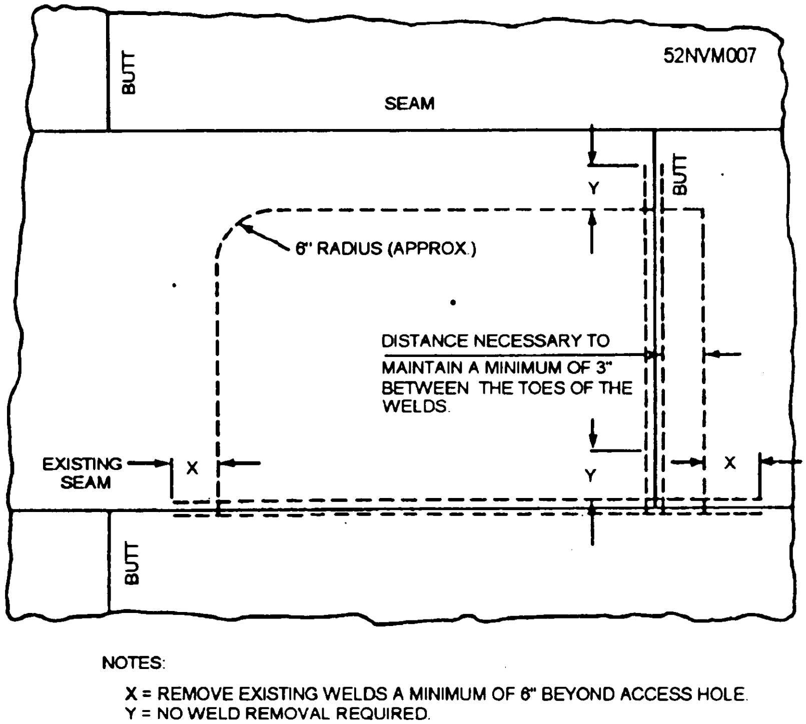


Figure 13-53.—Access holes intersecting existing welds.

- Cut no more than two holes in any tank.
- Cut holes to the minimum size necessary.
- Locate the edges of openings along existing butts or seams whenever practical.
- Locate holes between principle ship framing or bulkheads, cutting at least 3 inches from any of these members.

CUTTING THE ACCESS HOLE.—After you determine the location of the access hole, you are ready to make the cut. As a general rule, follow the requirements of the fabrication document, such as blueprints, technical manuals, or other approved documents, for laying out and cutting the access hole. If no fabrication document exists, use the following guidelines:

- Cut all comers except those involving existing butts or seams to a radius of 6 inches. The 6-inch radius in the comers is designed to eliminate stress associated with a 90-degree comer cut.
- Where corners involve butts or seams, remove the existing weld for a minimum distance of 6 inches beyond the existing butt or seam, as shown in figure 13-53.
- Maintain a minimum of 3 inches between the toes of two welds, as shown in figure 13-53.
- If crossing an existing butt weld, ensure that the new cut crosses the existing butt weld at a 90-degree angle.
- Cutouts involving riveted seams, or cuts closer than 6 inches to riveted seams, require the removal and replacement of the rivets for a distance of 6 inches from the weld area.

The first step in laying out the access cut is to remove all paint and rust from the cutting area. This will make the layout easier and the cutting process faster and cleaner. Using soap stone, lay out the new access cut, installing radii in the corners. You should then use a center punch to punch the outline of the cut. It is well worth the time to punch the outline to prevent having to lay out the outline again if it becomes erased accidentally. Install lifting padeyes if the patch is large in size or difficult to handle and tie it off before making the cut. The final step is to cut the access hole using a cutting torch or other method.

REINSTALLATION OF THE PATCH.—After the equipment has been removed and new equipment has been reinstalled, you will be required to reinstall the patch. If the removed plate is still usable, it should be reinstalled. If the plate cannot be reused, cut a new closure plate using the old plate as a guide. Determine the weld joint design to be used and bevel the patch and the bulkhead or hull to the required angle. Install the patch in place and check clearance as required by the weld joint design from MIL-STD-22.

WELDING IN CLOSURE PATCHES.—Welding of closure patches should be done by certified welders and inspected by NDT personnel. Welding is usually done using the block welding sequences to reduce weld metal cracking. You would usually weld the straight edges of the plate first and comers last to allow the comers to expand and reduce stress. If you are using a butt joint design, you must backgouge the root to remove impurities introduced during the welding process. This is usually accomplished after the first side is completely welded or enough weld metal has been deposited to allow for backgouging.

Cutting Access Holes Involving Previously Made Joints

When cutting access holes involving previously made cuts, cut in the center of the existing weld. If this is impractical or the access hole is required to be larger, follow the steps required for new access holes. If you must make the access cut larger or where more than two multiple cuts and replacements have been made, remove and replace the patch. Figure 13-54 shows patch removal involving more than two existing cuts and some of the typical mistakes made while making access cuts.

INSTALLING WATERTIGHT DOORS, HATCHES, AND SCUTTLES

As a shipfitter, you will replace numerous watertight fixtures in your career. This is a relatively easy process that involves no special skills. However, fixtures can be installed incorrectly if special precautions are not followed. When installing watertight closures, you should keep the following suggestions in mind:

- Ensure the watertight door has been properly maintained before cutting out the door. Some major problems with watertight fixtures are simply a lack of PMS and fixtures may not need to be replaced.
- Check the door and frame for warping. Sometimes the door is warped but the frame is straight. If the door is warped, replace the door. If the frame is warped, it must be cut out and replaced.

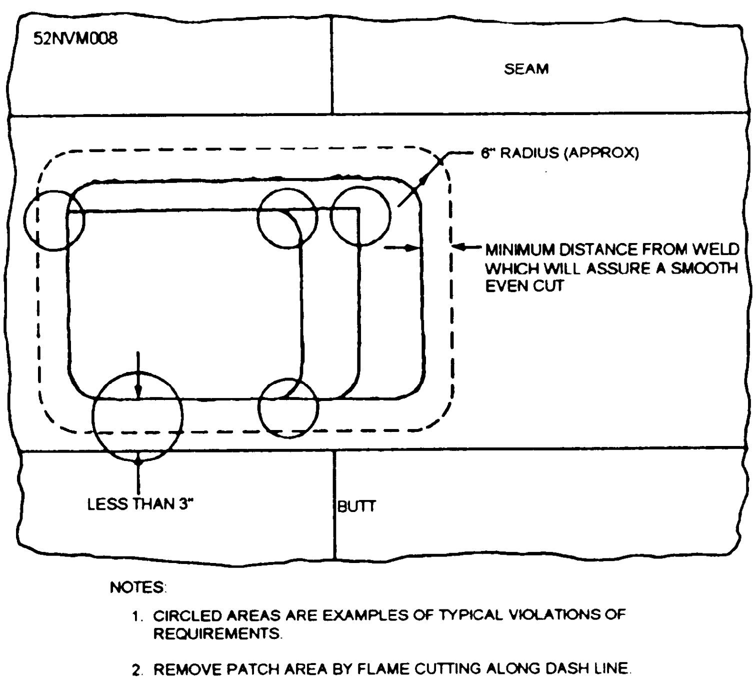


Figure 13-54.—Patch removal involving more than two existing multiple cuts.

If the frame is warped, it must be cut out and replaced.

- If removing the frame for a watertight door, do not cut the bulkhead. Watertight doors are welded in place using a lap joint. Only the weld metal should be removed.
- Weld repair any gouges or nicks in the bulkhead plating before reinstalling the door.
- When fitting the new frame and door in place, do not force the frame to the bulkhead. Instead, straighten the bulkhead. If the door is forced to the bulkhead, you will warp the frame.
- When welding in the new watertight fixture, ensure that the door is dogged tightly to the frame to prevent warping the door during welding.
- Perform a chalk test on the knife edge to the seal after the watertight door is installed according to the PMS card to ensure that the door was not warped during installation.

STOPPING CRACKS IN PLATE

In an emergency, you may stop a crack by drilling a hole that is 1/2T (where T is equal to the thickness of the plate) or 3/8 inch in diameter, whichever is the largest, and welding an overlay, as shown in figure 13-55, to arrest the crack. Drill the hole in the end of the crack, making sure that none of the crack extends beyond the drilled hole. An overlay of one layer is applied in the form of a trapezoid. This overlay is not to be any closer than one-half inch to the hole. No welding should be done on the crack nor within l/2 inch of the hole. The long dimension should be about 15 inches, with the deposit tapering away from the drilled hole to 10 inches at its 3 inch width. This will require ten to twelve passes. If possible, an overlay should be applied on both sides of the plate. A MIL-309 or 310-15/16 stainless steel 3/16-inch electrode is recommended. Care should be taken to fill craters and minimize arc strikes to prevent stress concentrations. After this temporary overlay has been accomplished, actual repair of cracks may be accomplished according to the requirements of the applicable fabrication document.

CORRECTING DISTORTION

Distortion (buckling or twisting) of structural steel members is caused by uneven expansion and contraction of the metal during welding. Distortion can be corrected by flame shrinkage (also known as flame straightening). Flame shrinkage is accomplished by directing a flame from a gas torch on an area where excess metal has accumulated as a result of earlier welding. The metal is displaced in the desired direction and the distortion is corrected or reduced. The operator of the torch must be able to recognize the areas of excess metal and determine the necessary amount of heat to apply.

Figure 13-56 shows how flame shrinkage is used to control expansion and contraction. In view A, the flame is directed toward a spot that is centrally located on a distorted steel plate. The spot heats up quickly and must expand. The cooler plate surrounding the distorted area prevents the spot from expanding along the plane of the plate, as shown in view B. This, in turn, will cause it to expand abnormally through its thickness, as shown in view C. Up to this point, the plate has actually thickened where the heat is applied. Upon cooling, the plate will contract uniformly in all directions, as shown in view D. When flame shrinkage is applied carefully, it will give a planned shrinkage that is useful for correcting distortion that was caused by previous heating and cooling cycles.

A high temperature is not required for flame shrinkage; however, a large torch tip should be used. The effectiveness of this process depends on your ability to rapidly change the temperature of the plate to a high degree at a given spot. A large torch will help to attain the required rapid temperature change. When a long piece of metal, such as the flange of a beam, needs to be flame shrunk, one of two methods should be used. You should either (1) move the torch progressively along the length, or (2) heat the metal at selected spots and then let it cool. You should make intermediate checks of the effect of the flame on the correction of the distortion as you go through this process.

Distortion Problems

Figure 13-57 shows a panel that has buckled due to welding stiffeners to it. There is an excess of metal between the stiffeners. If you apply the necessary heat in the proper areas, and allow it to contract upon cooling, you provide the shrinkage needed to straighten the panel. If the panel is under restraint (as is the case with many weldments), too much heating could cause

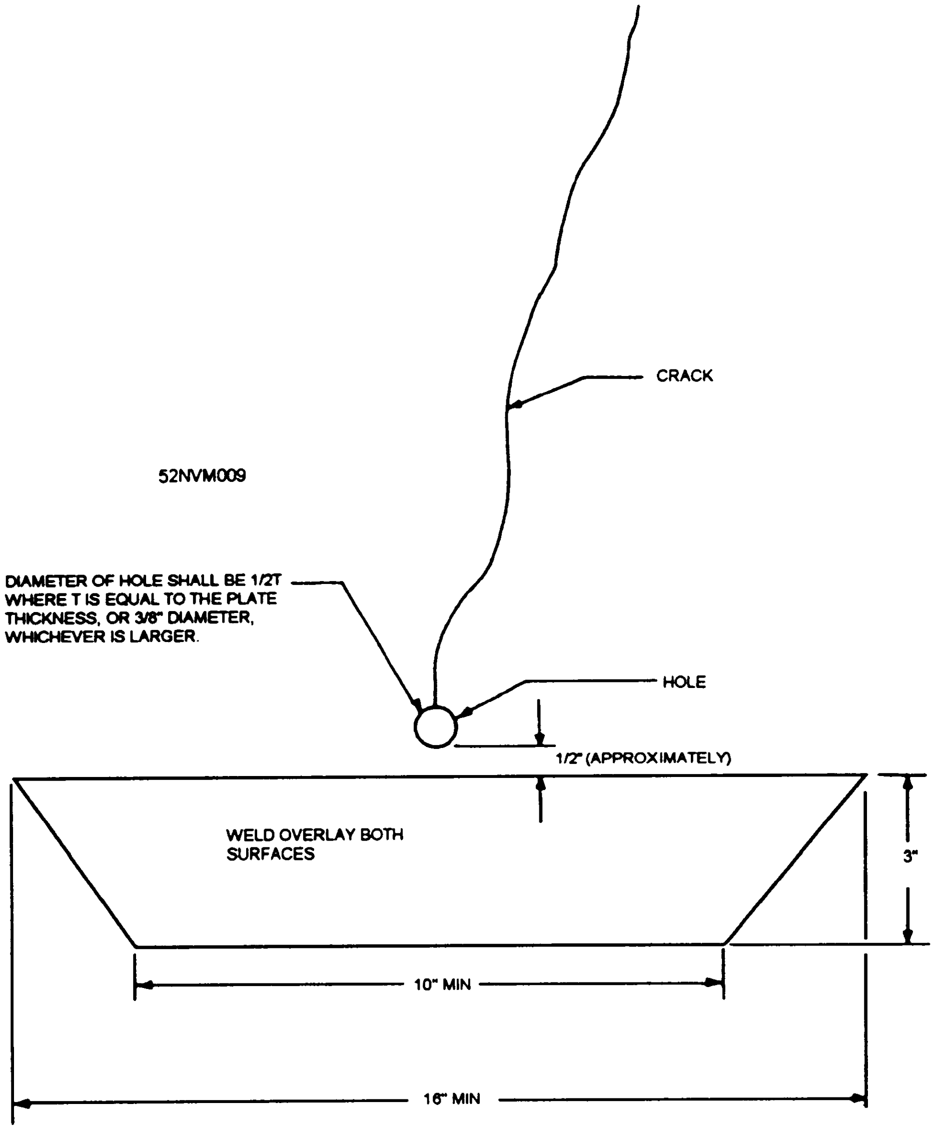


Figure 13-55.—Ductile metal overlay to arrest cracks in surface ship hull structure.

the development of locked-in stresses. When you use the flame shrinkage process, be sure you proceed cautiously, periodically allowing cooling to take place, and checking on the degree of distortion (buckling) removed.

A beam with a cover plate welded to it (fig. 13-58) is very likely to bend in the direction of the cover plate because the welding is not balanced about the neutral axis. Essentially, the act of welding on the cover plate produces shrinkage that shortens the length of the flange to which it is welded, as shown in view B of figure 13-58. You should then use flame shrinkage to shorten the other flange to the same length, thus straightening the beam as shown in view C of figure 13-58.

Flame shrinkage can also be used to give a beam a desired amount of curvature. Figure 13-59 shows a rolled beam with a cover plate welded to the lower flange. The bend resulting from the welding on the cover plate has not produced enough curvature and it is decided to use flame shrinkage to get the desired amount. How is this to be done?

If the cover plate alone is heated and shrunk, it will pull against the lower beam flange and you will get a considerable amount of locked-in tensile stress. Should the beam at some later time be accidentally overloaded, the yield point of the cover plate might be exceeded. This will cause stretching and some of the curvature will be lost. It would be desirable to minimize the tension stress developed in the cover plate by flame shrinkage so that a larger amount of the strength may be used to

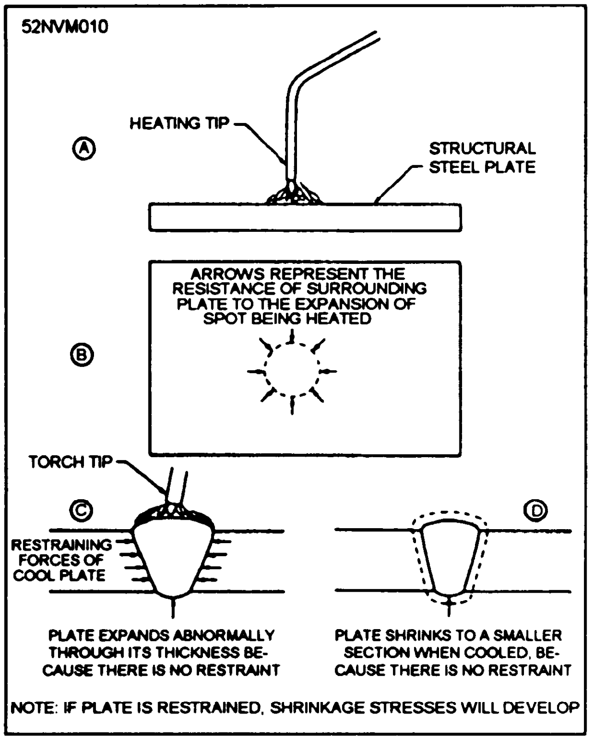


Figure 13-56.—Flame shrinkage used to correct distortion.

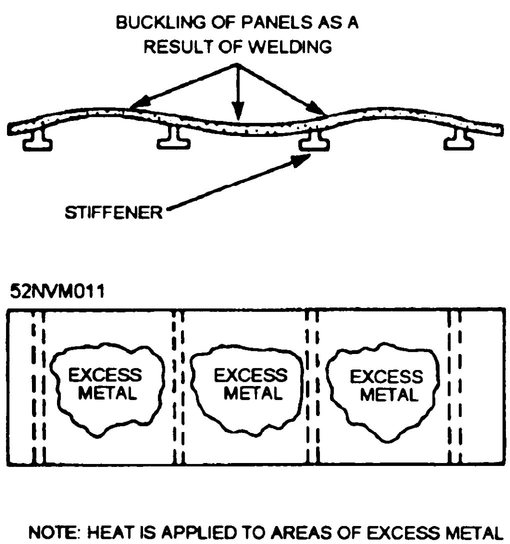


Figure 13-57.—Flame shrinkage used to control distortion of panels with welded stiffeners.

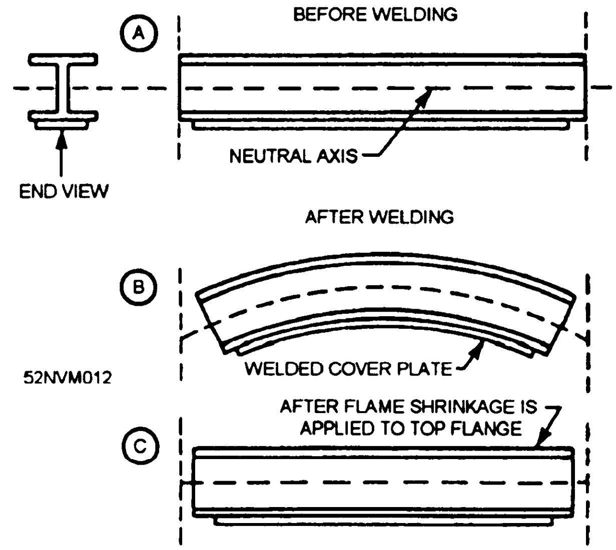


Figure 13-58.—Flame shrinkage used to straighten beam with a welded cover plate.

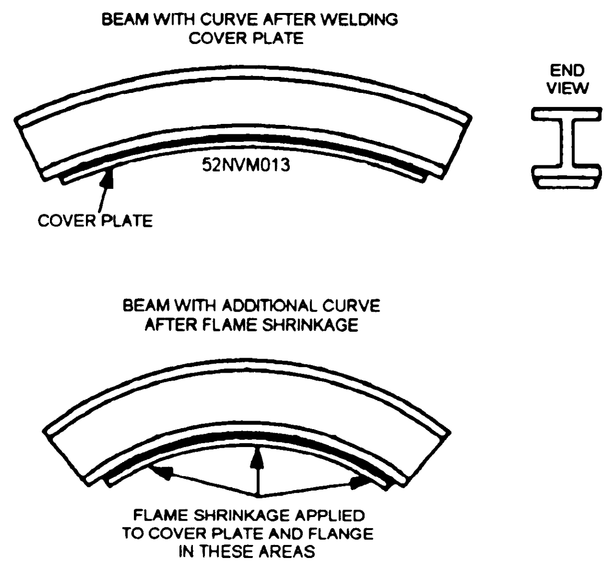


Figure 13-59.—Developing a curve in a beam.

resist the load and maintain the curvature. You can accomplish this by flame shrinking the beam flange along with the cover plate.

Figure 13-60 illustrates the technique of using flame shrinkage to develop curves in a beam or girder (with or without a cover plate) in such a way that little or no locked-in stress is developed. The rolled beam is straight at the start. A wedge-shaped area is marked off on the web and lower flange with soapstone. The wedged area is then heated to a dull red, using one or more torches. When the wedged area is a dull red, remove the heat and allow the area to cool. The curvature produced should then be noted. Then mark off other areas and repeat the process until you get the desired curvature.

This type of flame shrinkage produces the same results as if the entire beam had been heated red hot and bent to shape. There will be little or no locked-in stress

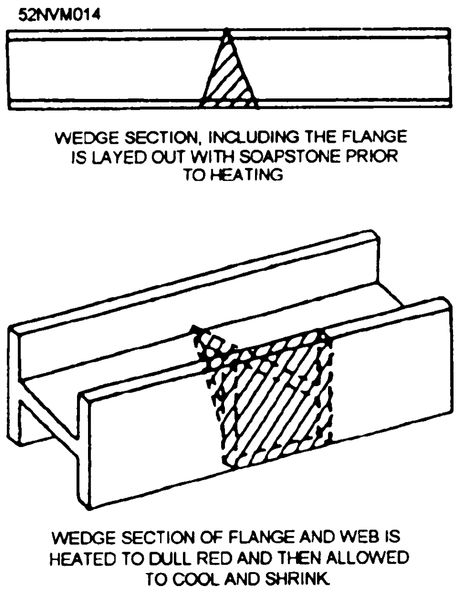


Figure 13-60.—Developing a curve without locked-in stresses.

and no danger of snapping the curve out later by accidental overload.

Water Spray Equipment

The water spray torch shown in figure 13-61 may be used to reduce cooling time. The torch consists of a nozzle, a "Y" fitting, a control valve, and a l/4-inch rubber hose. The air hose is connected to the ship's service compressed air and the rubber hose is run to a pail of water. When you open the control valve, the rush of air past the orifice in the "Y" fitting draws some water into the air stream, creating an atomized spray. When the spray strikes the hot plate, it turns into steam and absorbs a substantial amount of heat. One pound of water will absorb 142 Btu while vaporizing into steam. Because of the heat requirements for vaporization, the cooling is rapid, even with the use of only a small amount of water. Since all of the sprayed water is vaporized, the work will remain dry.

FABRICATION EXAMPLES

The variety of fabrication problems that arises on board ship is almost endless. The examples in this chapter are not to be considered as a complete listing of jobs you may have to perform.

The following basic considerations apply to most fabrication jobs:

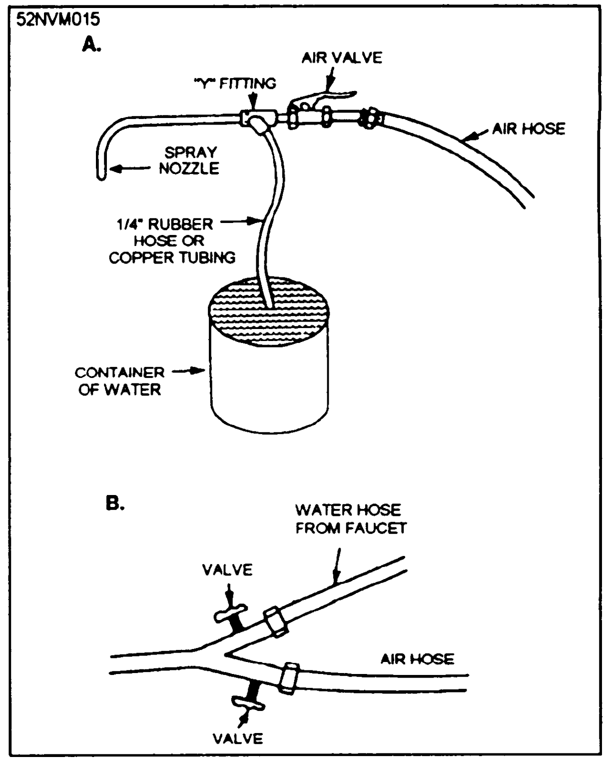


Figure 13-61.—Water spray torch used for reducing cooling time.

—Select the correct material for the job. Selecting materials for the fabricating plate structures is essentially a design problem, requiring a thorough knowledge of the properties of materials. The materials for most shipboard fabrication jobs are specified in the job order or on the blueprints. You must ALWAYS consult these sources of information before the material is selected. However, you should know enough about the properties of materials to be able to make an intelligent selection when this responsibility is left up to you.

—In making a repair or replacement, substitution of one material for another requires a knowledge of the service conditions that the piece must withstand. Low-carbon steel has an ultimate tensile strength of 60,000 psi and cast iron has an ultimate tensile strength of 20,000 psi. When you substitute low-carbon steel for cast iron, the cross-sectional area of the steel need only be one-third that of the cast iron if tensile strength is the ONLY consideration. In many cases, rigidity will be the controlling factor. When it is necessary to maintain the same rigidity, a low-carbon steel piece would have to be four-fifths the thickness of the cast-iron piece. When substituting another material for the one specified, you will have to find this type of information concerning the relationship between the two materials.

—Make full use of all available shapes, pieces, or subassemblies. For example, you can make many structures from standard rolled shapes and formed plate, joined together by welding. You can save both time and money by using available shapes.

Fabricating a Lever

The lever shown in figure 13-62 is made up of hubs and a formed box section. The hubs are cut from high-pressure tubing. The center box portion of the lever is formed from

l/4-inch rolled steel plate. Each half of the section is then bent to form a U-channel of the proper size and shape. The component parts are then assembled and joined by welding.

Fabricating a Bracket

The swinging knee bracket shown in figure 13-63 can be fabricated in several different ways just by using various structural shapes. By changing the design slightly, you can use a channel bar, an H-beam, or an I-beam just as well as the angle bar shown in the illustration. The cast bracket shown at the top of figure 13-63 weighed 570 pounds; the fabricated bracket made to serve the same purpose weighed only 317 pounds and cost 40 percent less than the cast bracket. As you can see, the parts were cut from various standard shapes and then welded together.

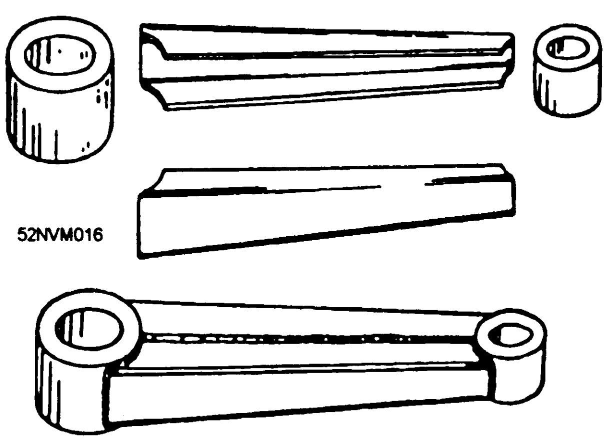


Figure 13-62.—Lever fabricated from high-pressure tubing and rolled steel plate.

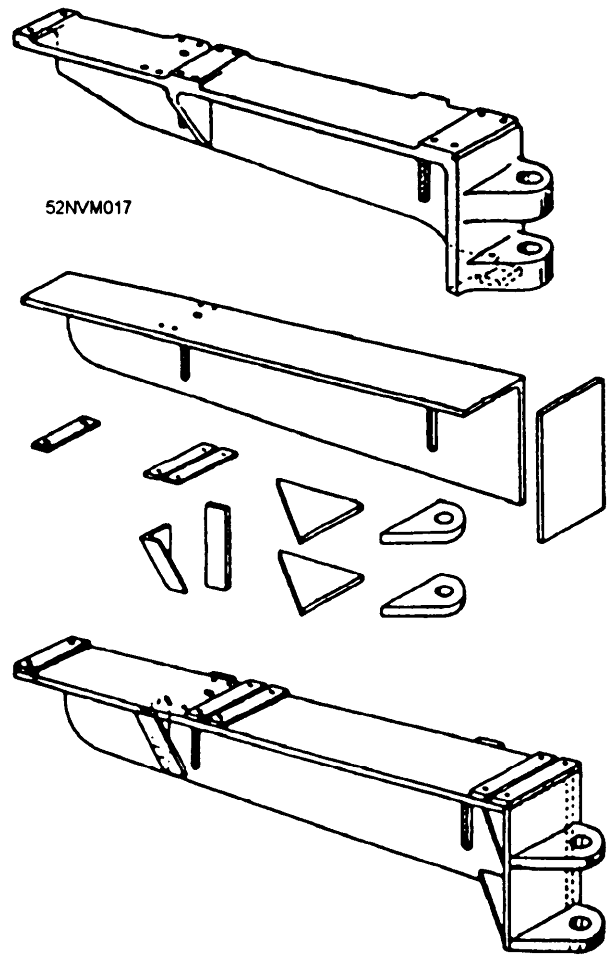


Figure 13-63.—Cast swing knee bracket (top) and fabricated swinging knee bracket.

Fabricating a Clevis

The clevis shown in figure 13-64 is another example of an item that can be made both lighter and cheaper by fabrication rather than by casting. Also note that the rough casting (top view) must be considerable thicker than the fabricated clevis. Although some of the excess metal would have to be machined off the rough casting, the casting would still have to be thicker than a fabricated clevis to serve the same purpose.

Fabricating Foundations and Supports

Bases, foundations, and supports are required for numerous pieces of equipment and machinery aboard ship. Figure 13-65 shows various bases and supporting members fabricated from standard shapes.

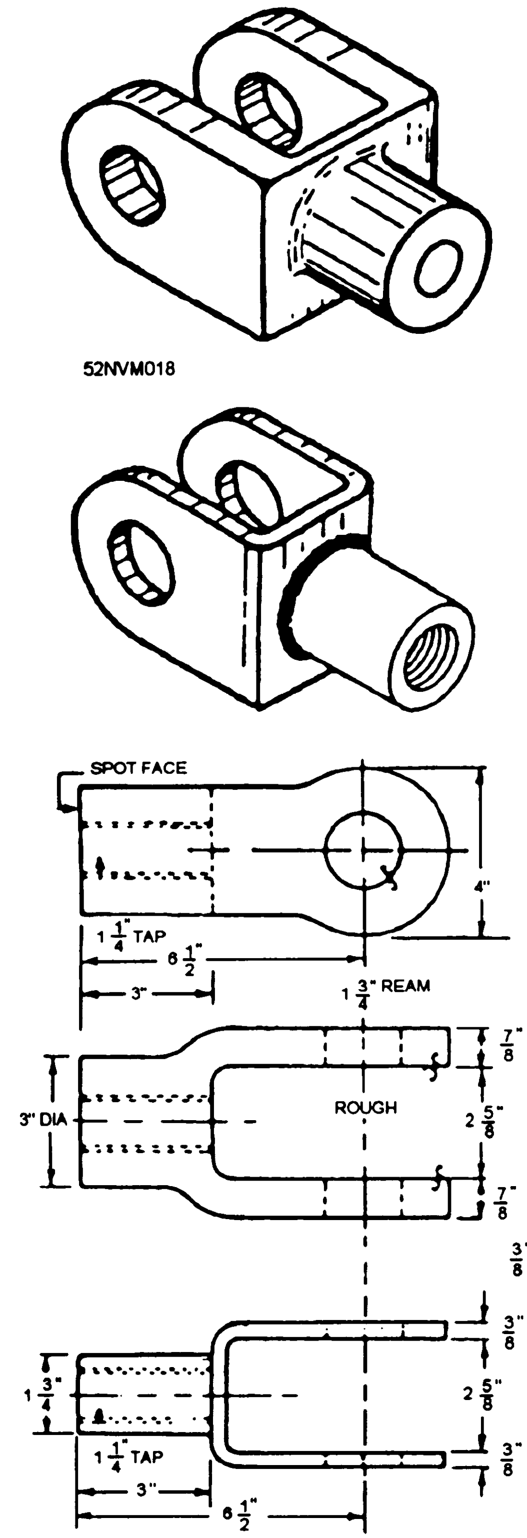


Figure 13-64.—Cast clevis (top) and fabricated clevis.

Fabricating Hinges

Hinges of many types and sizes can be drawn from stock. Once in awhile, you will find that you need an odd size or shape that is not available. You could forge the hinges, but it is usually quicker and cheaper to fabricate them in a manner shown in figure 13-66. The leaf is cut from a heavy gauge sheet metal. The eye is cut from either pipe or tubing. Small, lightweight hinges can be made from sheet metal, with the eye or sleeve being formed in much the same way that a wired edge is turned.

Fabricating a Padeye

Padeyes are installed aboard ships in areas where lifting of heavy items are required. Most ships, especially submarines, have detailed drawings that list the type and location of all permanently installed padeyes. Sometimes, you may have to fabricate padeyes in a particular size or shape, depending on the specific application and weight requirements. You should always manufacture padeyes according to blueprints or ship's drawings. If no blueprints exist for your ship, use a standard blueprint for padeyes before attempting to manufacture and install padeyes of any type. All padeyes subjected to any load, or where the safety of personnel might be endangered, must be tested before being put into service.

Fabricating a Scupper Drain

The scupper drain (fig. 13-67) may be made by rolling steel plate to a half round shape of the required diameter or by cutting a piece of pipe lengthwise in half. The half round pipe or rolled steel plate is then welded to a flat piece of plate that is slightly shorter and slightly wider than the drain. The flat plate is then bolted to clips that are welded to the shell of the ship. The scupper discharges water into the pipe just above the flat plate.

Fabricating a Boom Cradle

Another job sometimes needed on board ship is the fabrication of a boom cradle (fig. 13-68) to support a boom when it is not in use. A boom cradle can be made from a piece of plate of suitable thickness. Lay out the required dimensions on the plate. Use a cutting torch to cut a semicircular opening in the top of the plate to accommodate the boom. After the cradle has been cut out and ground smooth, it is ready to be welded to the deck.

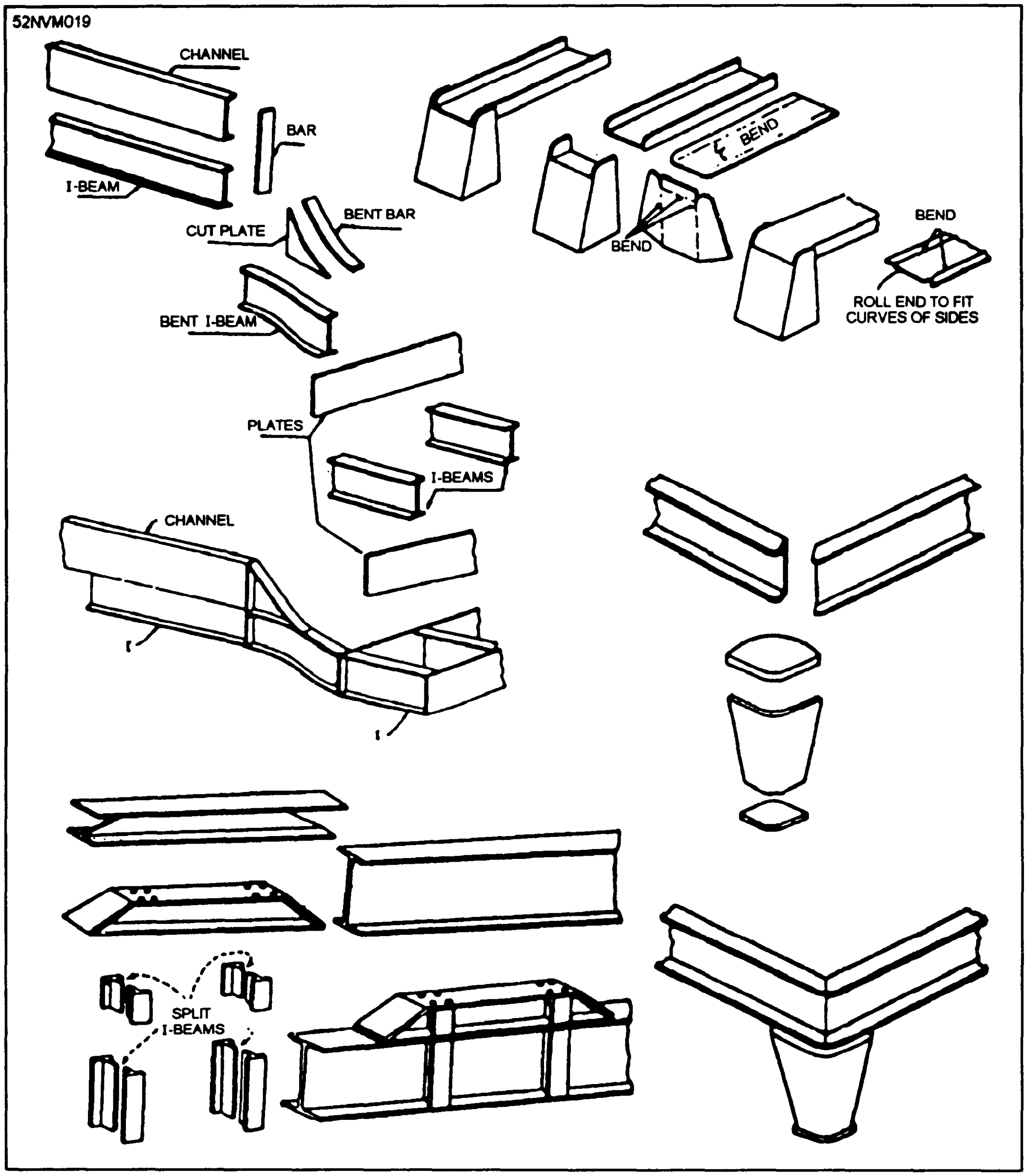


Figure 13-65.—Fabricated bases, foundations, and supports.

Fabricating Tanks

From time to time you may need to fabricate quench tanks, rinse tanks, or storage tanks. The material used in these tanks will vary from sheet metal to heavy plate, depending upon the use of the tank The shape and size of these tanks will depend upon the purpose of the tank, the space available for its installation, and its volume. Most of these tanks will either be rectangular or cylindrical in shape. Some of the larger tanks you might manufacture may require the installation of internal or external gussets, partitions, or stiffeners to support the tank walls.

To build a tank to blueprint specifications, you need to know how to convert fractions to decimals and figure the volume of squares, rectangles, and cylinders. Information on these mathematical computations can be found in chapter 14 of this manual and in *Mathematics,* Volume 1, NAVPERS 10069-D1.

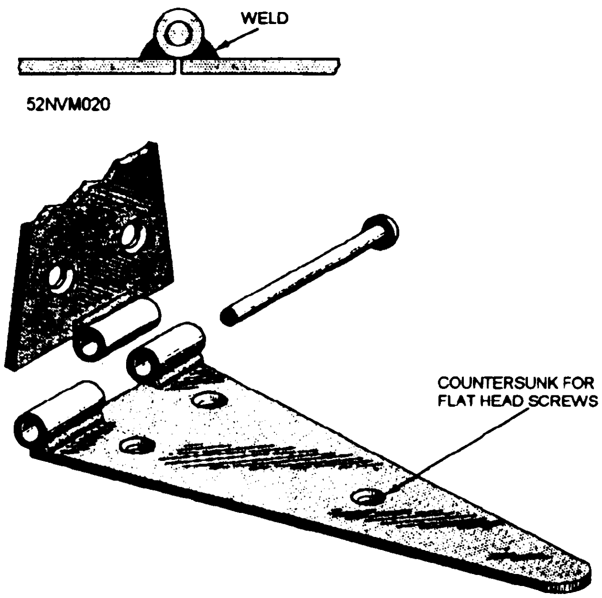


Figure 13-66.—Fabricated flat leaf hinge.

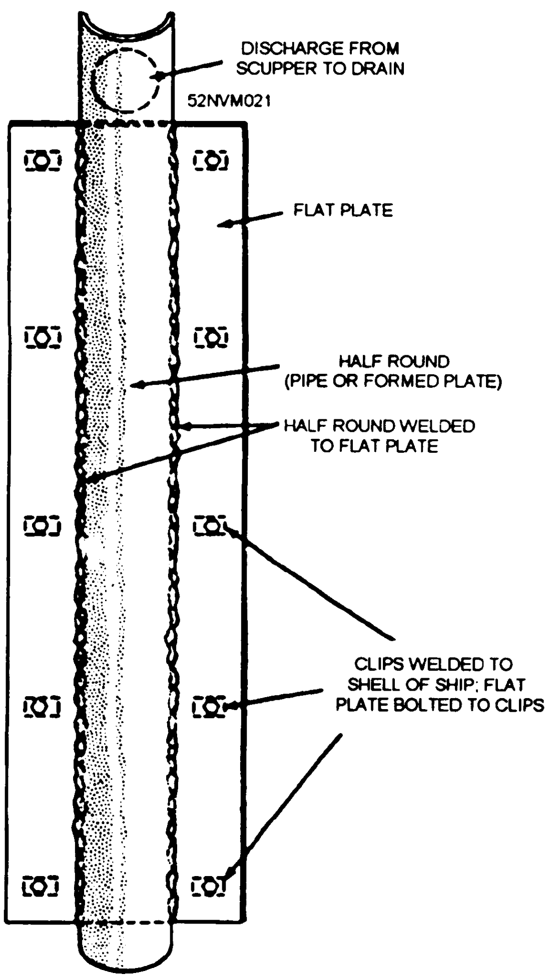


Figure 13-67.—Fabricated scupper drain.

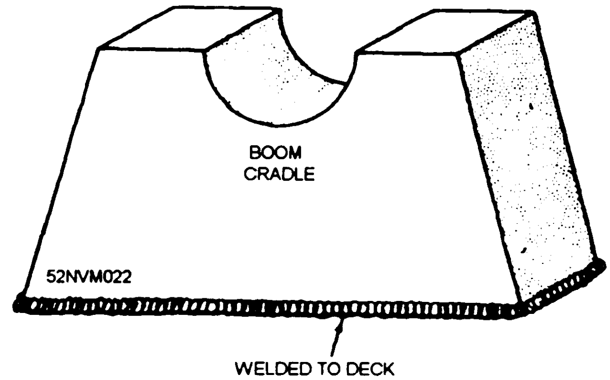


Figure 13-68.—Fabricated boom cradle.

SUMMARY

You may be assigned to a ship where the HT will work primarily in one area of the rating. You also may be assigned to a smaller ship where you will work in just about every one of the areas. Whatever ship you are assigned to, the information in this chapter will be helpful to you. It is quite common for the HT to either repair or replace items that have been damaged or that have deteriorated. The fabrication of new foundations, brackets, supports, padeyes, and other such items will almost be a daily job. Other personnel who have more experience will help you get your experience.

CHAPTER 14

SHOP MATHEMATICS

LEARNING OBJECTIVES

Upon completion of this chapter, you will be able to do the following:

- *Identify the fundamentals of the four branches of mathematics, and describe how they are related to the Hull Technician rating.*
- *Describe the method of geometric construction.*
- *Describe the methods of construction for several plane figures.*
- *Determine the areas and volumes of geometric shapes and figures.*
- *Describe the metric system, and convert the English system to the metric system.*

INTRODUCTION

Mathematics is as important a tool for you to use as a Hull Technician as are manual skills and good tools. It is a universal language that lets you understand measurements and values written in any language. HTs are constantly working with measurements and calculating weights and quantities of materials. HTs develop geometric outlines. This chapter is not a complete text in ship mathematics. Instead, it is a review of the basic mathematical knowledge you will need as a Hull Technician.

Tables of weights, measures, and equivalents are useful references when you are solving mathematical problems. This chapter contains a number of tables that you will use frequently.

If you desire further study of mathematics, you should request the following manuals through your educational services office:

Mathematics, Volume 1, NAVEDTRA 10069-D1

Mathematics, Volume 2-A, NAVEDTRA 10062-B

Mathematics, Volume 2-B, NAVEDTRA 10063

Mathematics, Volume 3, NAVEDTRA 10073-A1

FUNDAMENTALS OF MATHEMATICS

The basics of mathematics remain the same no matter what the field. Mathematics is divided into several different branches. You will be concerned with arithmetic, algebra, geometry, and trigonometry.

Arithmetic deals with the manipulation of numbers, using addition, subtraction, multiplication, and division.

Algebra uses letters and symbols in place of numbers and values. These letters and symbols construct equations that follow established mathematic rules.

Geometry investigates the relationships, properties, and measurements of solids, plane surfaces, lines, angles, graphs, and other geometric characteristics.

Trigonometry investigates the properties of triangles and of trigonometric functions and their applications.

COMMON FRACTIONS

Common fractions are often used in sheet metal layout, woodworking, piping repairs, and structural repairs. Most of your measuring devices, such as the shrink rule, are divided into common fractional increments.

The common fraction is a simple method of expressing the division of a whole number or object. Fractions show one or more parts divided into any number of equal parts. Examples are dividing 1 inch into four equal parts or dividing a line into four equal parts. These equal parts are expressed as increments of one—fourth. You know that four increments equal the whole number or object. You can write any part less than the whole as a common fraction, such as l/4 or 3/4.

The common fraction contains two parts—the denominator and the numerator. The denominator shows how many equal parts the whole divides into. The numerator shows the number of equal parts being considered.

Example: $\dfrac{5\ (\text{Numerator})}{8\ (\text{Denominator})}$

DECIMAL FRACTION

A decimal fraction is a fraction whose denominator is 10 or some multiple of 10, such as 100, 1,000, or 10,000. *Decimal fractions differ from common fractions in that the denominators are not written but are expressed by place value.* Figure 14-1, views A and B, shows a place value chart. As we proceed from left to right in place value, the value of each place is one-tenth the value of the preceding place. Notice in views A and B that the units place is the center of the system and that the place values proceed to the right or left by powers of ten. Ten on the left is replaced by tenths on the right, hundreds by hundredths, thousands by thousandths, and so on. Notice that each decimal fraction begins with a period. This period is called a decimal point. To call attention to the decimal point, we usually begin the decimal fraction with a zero.

Examples of decimal fractions, their equivalent common fractions, and how you read them are as follows:

$0.3 = \dfrac{3}{10}$ = three tenths

$0.07 = \dfrac{7}{100}$ = seven hundredths

$0.023 = \dfrac{23}{1000}$ = twenty–three thousandths

$0.1276 = \dfrac{1276}{10000}$ = one thousand two hundred seventy–six ten–thousandths

A mixed decimal is an integer and a decimal fraction combined. We use a decimal point to separate the integer portion from the decimal fraction portion.

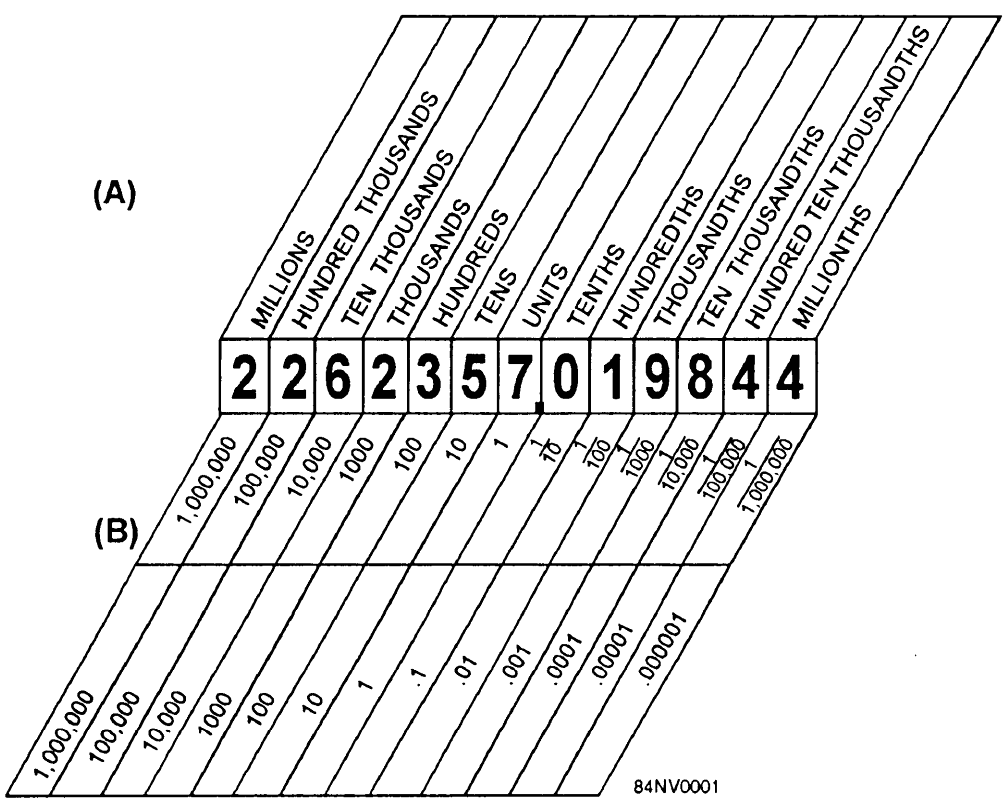


Figure 14-1.—Place value chart.

The following are examples of mixed decimals, their equivalent mixed numbers, and how they are read:

$$160.32 = 160\frac{32}{100} = \text{one hundred sixty and thirty–two hundredths}$$

$$21.005 = 21\frac{5}{1000} = \text{twenty–one and five thousandths}$$

A decimal is any number written with a decimal point, which includes decimal fractions and mixed decimals. For the rest of the manual, we will refer to decimal fractions and mixed decimals as decimals.

Equivalent Decimals

From our study of fractions, it should be clear that

$$\frac{5}{10} = \frac{50}{100} = \frac{500}{1000}$$

Writing the same values as decimals would be equivalent to

0.5 = 0.50 = 0.500

In other words, the value of a decimal is not changed by attaching zeros to the right of any decimal point after the last digit.

Converting Fractions to Decimals

One way to convert a fraction to a decimal is to divide the numerator by the denominator. To obtain our answer, we will attach as many zeros after the understood decimal point in the numerator as needed, since we have determined this will not change the value of our numerator.

Example: Convert 3/5 to a decimal.

Solution:

$$\begin{array}{r}
0.6 \\
5\overline{)3.0} \\
\underline{0} \\
3\,0 \\
\underline{3\,0} \\
0
\end{array}$$

So the answer is 3/5 = 0.6. Notice that the decimal point in the quotient was placed directly above the decimal point of the number we are dividing into.

Example: Convert -7/32 to a decimal

Solution:

$$\begin{array}{r}
-0.21875 \\
32\overline{)(-)7.00000} \\
\underline{0} \\
7\,0 \\
\underline{6\,4} \\
60 \\
\underline{32} \\
280 \\
\underline{256} \\
240 \\
\underline{224} \\
160 \\
\underline{160} \\
0
\end{array}$$

Therefore, -7/32 = -0.21875.

Example: Convert 51/8 to a decimal.

Solution:

$$\begin{array}{r}
6.375 \\
8\overline{)51.000} \\
\underline{48} \\
3\,0 \\
\underline{2\,4} \\
60 \\
\underline{56} \\
40 \\
\underline{40} \\
0
\end{array}$$

Hence, 51/8 = 6.375.

The answers in the examples just covered were all considered terminating decimals since each quotient terminated or ended. A repeating decimal will have a repeating pattern and never terminate.

Example: Convert l/3 to a decimal.

Solution:

$$\begin{array}{r}
0.333... \\
3\overline{)1.000} \\
\underline{9} \\
10 \\
\underline{9} \\
10 \\
\underline{9} \\
1
\end{array}$$

As you can see, there is a repeating pattern of 3. We will represent the repeating digits with a bar over the repeating pattern. Therefore, l/3 = $0.\overline{3}$.

Example: Convert -25/11 to a decimal.

Solution:

$$\begin{array}{r@{}l} & \;\;-2.2727\ldots \\ 11 & \overline{\big)(-)25.0000} \\ & \underline{22} \\ & \;\;30 \\ & \;\;\underline{22} \\ & \;\;\;80 \\ & \;\;\;\underline{77} \\ & \;\;\;\;30 \\ & \;\;\;\;\underline{22} \\ & \;\;\;\;\;80 \\ & \;\;\;\;\;\underline{77} \\ & \;\;\;\;\;\;3 \end{array}$$

Hence, -25/11 =2.$\overline{27}$.

You may find it of interest to know that if the denominator of a common fraction reduced to lowest terms is made up of prime factors of just 2s or just 5s or both, the fraction can be converted to an exact or terminating decimal.

Another way to convert a fraction to a decimal is to express the fraction as an equivalent fraction whose denominator is a multiple of 10, such as 10, 100, 1000. Then, change the fraction to adecimal. You will always get a terminating decimal with this method.

Example: Convert 3/4 to a decimal.

Solution:

$$\frac{3}{4}=\frac{3\times 25}{4\times 25}=\frac{75}{100}=0.75$$

Example: Convert -47/200 to a decimal.

Solution:

$$\frac{-47}{200}=\frac{-47\times 5}{200\times 5}=\frac{-235}{1000}=-0.235$$

Example: Convert -11/8 to a decimal.

Solution:

$$\frac{-11}{8}=\frac{-11\times 125}{8\times 125}=\frac{-1375}{1000}-1\,\frac{375}{1000}=-1.375$$

Example: Convert 102/25 to a decimal.

Solution:

$$\frac{102}{25}=\frac{102\times 4}{25\times 4}=\frac{408}{100}=4\,\frac{8}{100}=4.08$$

In the two previous examples, the fractions could have been expressed as mixed numbers and then converted to decimals. To convert a mixed number to a decimal, leave the integer portion as it is and convert the fractional portion to a decimal.

Example: Convert -15 2/5 to a decimal.

Solution:

$$-15\,\frac{2}{5}=\left[15+\left(\frac{2\times 2}{5\times 2}\right)\right]=-15\,\frac{4}{10}=-15.4$$

Example: Convert 2 5/16 to a decimal.

Solution:

$$2\,\frac{5}{16}=2+\left(\frac{5\times 625}{10\times 1000}\right)=2+\left(\frac{3125}{10000}\right)=2.3125$$

Example: Convert 3 5/6 to a decimal.

Solution: Since the denominator 6 is not made up of just 2s or just 5s or both, we will have to divide 6 into 5 to obtain a repeating decimal and then add 3 to our answer.

$$\begin{array}{r@{}l} & \;0.83333\ldots \\ 6 & \overline{\big)5.0000} \\ & \underline{4\,8} \\ & \;\;20 \\ & \;\;\underline{18} \\ & \;\;\;20 \\ & \;\;\;\underline{18} \\ & \;\;\;\;20 \\ & \;\;\;\;\underline{18} \\ & \;\;\;\;\;2 \end{array}$$

Therefore, 3 5/6 = 3.$\overline{83}$.

Example: Convert -61 13/15 to a decimal.

Solution:

$$\begin{array}{r@{}l} & \;\;0.8666\ldots \\ 15 & \overline{\big)13.0000} \\ & \underline{12\,0} \\ & \;1\,00 \\ & \;\;\underline{90} \\ & \;\;100 \\ & \;\;\;\underline{90} \\ & \;\;\;100 \\ & \;\;\;\;\underline{90} \\ & \;\;\;\;100 \\ & \;\;\;\;\;\underline{90} \\ & \;\;\;\;\;10 \end{array}$$

Therefore, -61 13/15 = -61.$\overline{86}$.

We could also convert a fraction to a decimal to a particular decimal place.

Example: Convert 25/16 to a decimal to the nearest tenth.

Solution:

$$\frac{25}{16}=\frac{25\times 625}{16\times 625}=\frac{15625}{10000}=1.5625$$

So, 25/16 = 1.6 to the nearest tenth.

Example: Convert -72 5/11 to a decimal to the nearest hundredth.

Solution: In this case, you would divide 5 by 11 to one place past the desired place value of hundredths and then round.

$$\begin{array}{r} 0.454 \\ 11\overline{)5.000} \\ \underline{4\,4} \\ 60 \\ \underline{55} \\ 50 \\ \underline{44} \\ 6 \end{array}$$

So, -72 5/11 = -72.45 to the nearest hundredth.

Converting Terminating Decimals to Fractions

To convert a terminating decimal to a fraction, count the number of digits to the right of the decimal point. Move the decimal point that many places to the right, and write the answer you get over a denominator beginning with 1 followed by as many zeros as places moved to the right. Reduce to lowest terms, if possible.

Example: Convert 0.77 to a fraction.

Solution: The number of digits to the right of the decimal point is 2. Therefore, we will move the decimal point 2 places to the right and place 77 over 100. So

$$0.77 = \frac{77}{100}$$

Example: Convert -0.045 to a fraction and reduce to lowest terms.

Solution:

$$-0.045 = \frac{-45}{1000}$$

$$= \frac{-9}{200}$$

When converting mixed decimals to fractions, you will usually find it is easier to keep the integer portion as an integer and change the decimal fraction to a common fraction.

Example: Convert 12.625 to a fraction and reduce to lowest terms.

Solution:

$$12.625 = 12\,\frac{625}{1000}$$

$$= 12\,\frac{5}{8}$$

Example: Convert -200.4 to a fraction and reduce to lowest terms.

Solution:

$$-200.4 = -200\,\frac{4}{10}$$

$$= -200\,\frac{2}{5}$$

Converting Repeating Decimals to Fractions

Converting a repeating decimal to a fraction is a little more confusing than the conversions we have previously performed. A repeating decimal can be converted to a fraction by the following steps:

1. Form an equation letting n equal the repeating decimal.
2. Multiply both sides of the equation by a multiple of 10 in order to shift a set of the repeating pattern.
3. Subtract the original equation from the new equation (in step 2).
4. Solve for *n* and reduce to lowest terms.

Example: Convert $0.\overline{2}$ to a fraction.

Solution: First, let n equal the repeating decimal, or

$n = 0.222...$

Second, multiply both sides of the equation by 10 since there is only one digit in the repeating pattern. Hence,

$10n = 2.222...$

Third, subtract the original equation from the new equation. That is,

$$\begin{array}{r} 10n = 2.222... \\ \underline{-\quad n = 0.222...} \\ 9n = 2.000... \end{array}$$

Fourth, solve for *n*.

$9n = 2$

$$\frac{9n}{9} = \frac{2}{9}$$

$$n = \frac{2}{9}$$

Therefore, $0.\overline{2} = 2/9$.

Example: Convert $5.\overline{63}$ to a fraction and reduce to lowest terms.

Solution: Let

$n = 5.636363...$

Multiply both sides by 100, since there are two repeating digits.

$100n = 563.636363...$

Subtract the original equation from the new equation.

$$\begin{array}{r} 100n = 563.636363... \\ - \quad n = \quad 5.636363... \\ \hline 99n = 558 \end{array}$$

Solve for n and reduce to lowest terms.

$$99n = 558$$

$$\frac{99n}{99} = \frac{558}{99}$$

$$n = \frac{558}{99} = \frac{62}{11} \text{ or } 5\,\frac{7}{11}$$

Hence, $5.\overline{63} = 57/11$.

For the previous problem we could have kept the integer portion as an integer and converted the repeating decimal to a fraction.

Example: Convert $-38.\overline{054}$ to a fraction and reduce to lowest terms.

Solution: We will retain -38 and work with .

$$\begin{array}{r} 1000n = 54.054054... \\ - \quad n = \quad 0.054054... \\ \hline 999n = 54 \end{array}$$

$$n = \frac{54}{999} = \frac{2}{37}$$

Therefore, $-38.\overline{054} = -38\ 2/37$.

Example: Convert $-12.\overline{637}$ to a fraction.

Solution:

$$\begin{array}{r} 100n = 63.73737... \\ - \quad n = \quad 0.63737... \\ \hline 99n = 63.1 \end{array}$$

$$n = \frac{63.1}{99} = \frac{631}{990}$$

Hence, $-12.\overline{637} = -12\ 631/990$.

PERCENTAGE

Percentage is the expression of numbers in hundredths. The percent sign (%) is used to show percentage. Three terms apply to percentage problems—*base, rate*, and *percentage*. The base is the number upon which a percent is calculated. The rate is the amount of the percent. The percentage is the result of the calculations made with the base and rate. For example, 2% of \$125.00 equals \$2.50. The rate is 2%. The base is \$125.00. The percentage is \$2.50.

Percentage is calculated as a decimal fraction. Therefore, the rate must be a decimal fraction. For example, 2% and 25% are equal to 2/100 and 25/100, respectively. Convert these to 0.02 and 0.25, respectively. Write a rate of 100% as 1.00, 225% as 2.25, and so on.

RATIO AND PROPORTION

You can use ratio and proportion to solve problems quickly and reduce the chances of error.

Ratio

A ratio is a method of comparing two numbers or values in fractional form. For example, a fast frigate has a top speed of 30 knots and a cargo ship has a top speed of 15 knots. You can easily compare their speeds. This comparison can be written as 30:15 and 30/15. This makes the fractional form easier to calculate. To simplify the comparison, you reduce the fraction 30/15 to its simplest form of 2/l. Now, you can use this fraction form of a comparison very easily when calculating.

Comparison by a ratio is limited to quantities of the same kind. To express the ratio between 6 feet and 3 yards, both quantities must be in like terms. The proper forms of this ratio would be either 2 yards:3 yards or 6 feet:9 feet. Mathematically, like terms cancel each other. The yards or feet would cancel each other and the resulting ratio would read 2:3 or 6:9.

Proportion

Closely related to the study of ratio is the subject of proportion. The term *proportion* is defined as a relation of equality. A proportion is nothing more than an equation of two ratios that are equal to each other. Proportion can be written in three different ways, as shown in the following examples:

Example 1: 15:20::3:4

Example 2: 15:20 = 3:4

Example 3: $\frac{15}{20} = \frac{3}{4}$

As shown in the examples, a proportion is nothing more than an equation of common fractions. The value of proportion is that if any three of the terms are given, the fourth or unknown term can be found. This is done by solving a simple problem of common fractions.

GEOMETRIC CONSTRUCTION

Patterns are geometric shapes that conform to a draftsman's plan (blueprint) and contain allowances for draft, shrinkage, and machine finish. To construct a pattern, you must solve graphics problems of geometric construction. Graphics problems can be solved by trial and error or by measuring with a scale. However, neither method is accurate; therefore, they cannot be used in patternmaking. Because of its accuracy, only the geometric method of construction should be used in patternmaking. No other method is acceptable.

NOTE: You will need specific tools to USC during geometric construction. Sonic of these tools include a pencil divider, a 12-inch scale, a flexible straightedge, a 30- to 60-degree triangle, and a T-square.

As you read about geometric construction, the discussion will contain some geometric terms that you should know. These terms arc defined as follows:

Angle—A figure formed by two lines converging on a common point .

Apex—The highest point of a triangle.

Arc—A portion of a circle or curve.

Bisect—To divide into two equal parts.

Circumference—The distance around a circle, ellipse, or closed curve.

Curve—Any geometric line or shape that is not straight, contains no angles, and does not form a closed figure.

Diameter—The distance from a point on the circumference of a circle, through the center, to the opposite point on a circle.

Hypotenuse—The side of a right triangle that is opposite the right angle.

Intersect—To meet and cross at a point or series of points. Two lines intersect at one point. Two plants intersect at a series of adjacent points (which is the definition of a line).

Parallel—Maintaining an equal distance at all points on two or more lines or plants.

Perpendicular—Right angles (90°) to a line or plane.

Plane—A two—dimensional geometric figure.

Point—The intersection of two lines. A point has no dimensions.

Polygon—Any closed figure having three or more sides.

Radius—The distance from the center of a circle to the circumferece of that circle (one-half of the diameter).

Tangent—A curved or straight lint that touches but does not cross another curved or straight line at a point other than its ends.

Vertex—The point of intersection of two lines forming an angle.

BISECTING A LINE

As you read this section, refer to figure 14-2. You arc going to learn how to bisect a line by using the following steps:

1. USC your dividers and adjust them with a spread that is visually greater than one-half the length of the line.
2. Insert one point of the dividers at one end of the line (point A, view A) and draw an arc. Be careful not to change the adjustment on the dividers.
3. Insert one point at the other end of the line (point B, view B) and draw an arc from that end intersecting the first arc.
4. Draw a straight line connecting the two intersection points of the arcs to bisect the line (view C).

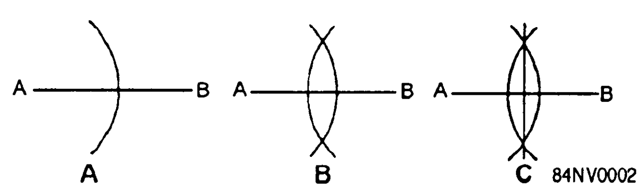


Figure 14-2.—Bisecting a line.

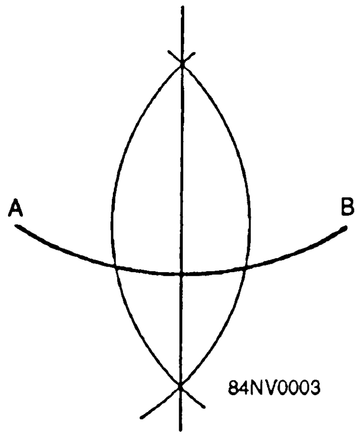


Figure 14-3.—Bisecting an arc.

BISECTING AN ARC

To bisect an arc, you should follow the same steps as those given for bisecting a line. Use the ends of the arc (points A and B in fig. 14-3) as centers for the arcs that intersect.

BISECTING AN ANGLE

Look at figure 14-4 as you read about bisecting an angle. Use the following steps to bisect an angle:

1. Use the vertex of the angle as the center for one point of the dividers. Draw arcs cutting the legs of the angle (view A).
2. Use the intersections of the arcs and the legs as centers to draw arcs that intersect each other inside the angle (view B).
3. Connect the intersection point of these last two arcs with the vertex of the angle to bisect the angle (view C).

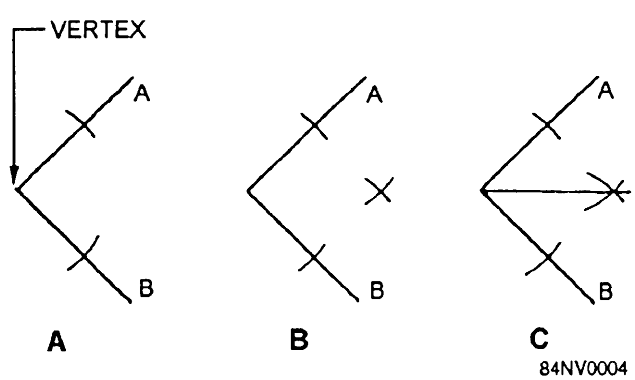


Figure 14-4.—Bisecting an angle.

COPYING OR TRANSFERRING AN ANGLE

A simple geometrical method can be used to copy or transfer an angle. Figure 14-5 shows you how to do this. To use this method, use the following steps to copy angle AOB onto base line B´O´:

1. Insert one point of the dividers at point 0 (view A). Adjust the other leg to intersect line A´O´ at a distance that is convenient to work with.
2. Draw an arc that intersects both legs of the angle (view A).
3. Look at view B. Without changing the adjustment on the dividers, place the point on point O´ and draw an arc intersecting the base line.
4. Look at view C. Use the dividers to measure between the legs of the angle where the arc cuts the legs. Transfer this measurement to line O´B´ by placing one point of the dividers at the intersection of line O´B´ and the transferred arc. Draw a short arc that intersects the transferred are (view C).
5. Connect the intersection point of the two arcs to point O´ to draw leg A´O´ and form A´O´B´ (view D).

DIVIDING A LINE INTO FIVE EQUAL PARTS

You may wonder, why not just measure and divide into the required number of parts? This is not a very

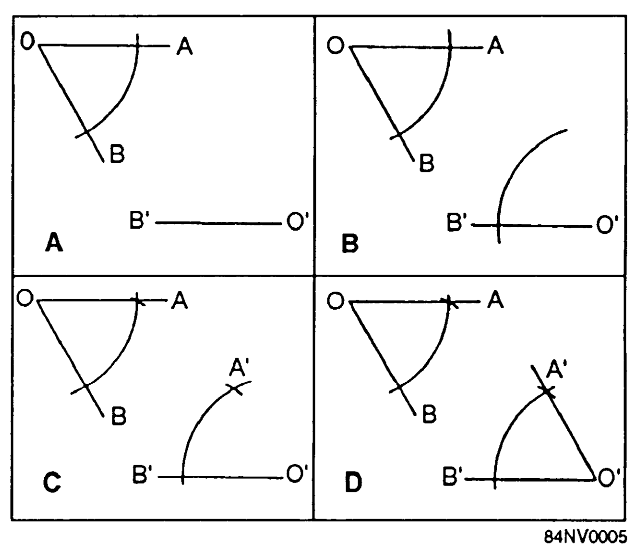


Figure 14-5.—Copying an angle.

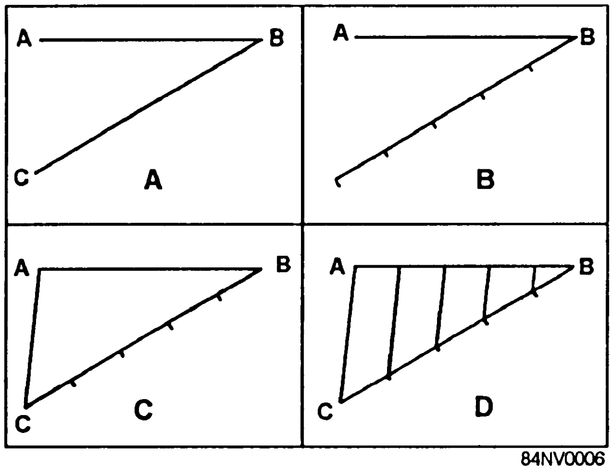


Figure 14-6.—Dividing a line geometrically.

accurate way to divide a line. A more accurate division can be made by using dividers. You may divide a line into any number of equal parts by using the following procedure (fig. 14-6):

1. Draw a line at an angle from one end of line AB (view A).
2. On this line mark off five equal points with dividers (view B).
3. Draw a line from the last point at the widest part of the angle (point C in view C) to the end of the original line (point A). This line is shown as AC in view C.
4. From each of the other marked-off points, draw lines parallel with line AC (view D).

DRAWING A CIRCLE OR AN ARC THROUGH THREE GIVEN POINTS

The steps used in drawing a circle through three given points are given in the following list and are shown in figure 14-7, which you should refer to as you read this section.

1. Draw lines between points A, B, and C, and bisect these lines (view A).
2. The point where the bisecting lines intersect each other (point D) is the center of the circle. Place one point of the dividers at this point and the other point at one of the other three lettered points.
3. Draw the circle as shown in view B. The circle will now pass through all three lettered points.

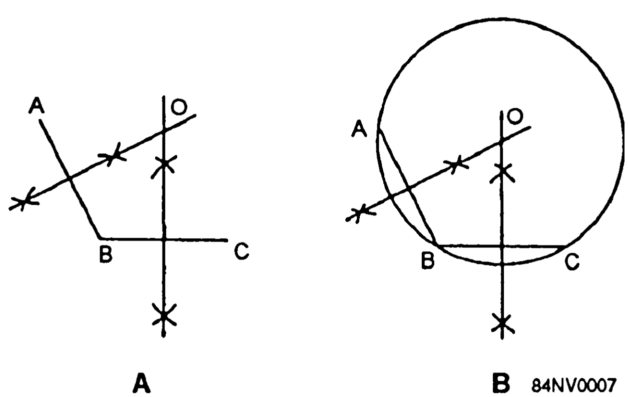


Figure 14-7.—Drawing a circle through three given points.

DRAWING A PERPENDICULAR FROM THE END OF A LINE

Figure 14-8 shows the steps you will follow to draw a perpendicular from the end of a line.

1. Pick any point, such as C, above base line AY.
2. With the dividers set at a radius of CA, place the point at point C. Draw an arc so the arc intersects line AY at point B. It must extend an equal distance on the other side of A.
3. Draw a line intersecting the arc through points B and C. Label this point D.
4. Then, draw line DA perpendicular to line AY.

DRAWING A PERPENDICULAR TO A GIVEN LINE FROM A GIVEN POINT

At times, you will need to draw a perpendicular to a given line from a given point. The steps for drawing

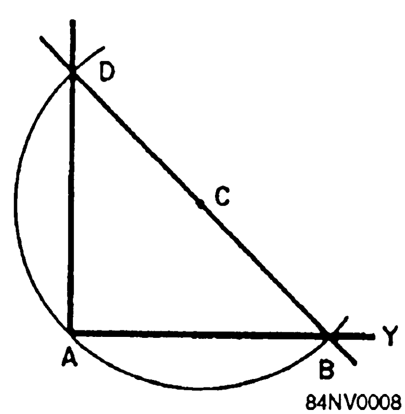


Figure 14-8.—Drawing a perpendicular from the end of the line.

a perpendicular to a given line from a given point are shown in figure 14-9.

1. From point A above line XY, pick any two points on line XY, such as C and B. Points C and B can either be on opposite sides of A or both on the same side of A.
2. With B as a center, and with a radius of BA, draw short arcs above and below line XY.
3. With C as a center, and a radius of CA, draw short arcs intersecting the arcs drawn in step 2.
4. Draw line DA through the intersecting arcs. Line DA is perpendicular to line XY.

BLENDING ARCS AND TANGENTS

Laying out circles or arcs, and straight lines tangent to them, is difficult. It is difficult because there is an element of optical illusion involved. Drawing a straight line to a curved one is easier than drawing a curved line to a straight one. Because of this, major circles or arcs are drawn first on layouts.

Even when you draw a straight line to a curve, an optical illusion may make it difficult for you to blend the curve and the line perfectly. This section discusses a few simple methods that should help you to blend lines and arcs.

The Draftsman's Method of Drawing a Tangent to a Circle at a Given Point

The draftsman's method of drawing a tangent to a circle is described in the following steps. It is shown in figure 14-10, and you should refer to this figure as you read this section. You will need your triangle and straightedge to draw a tangent to a circle.

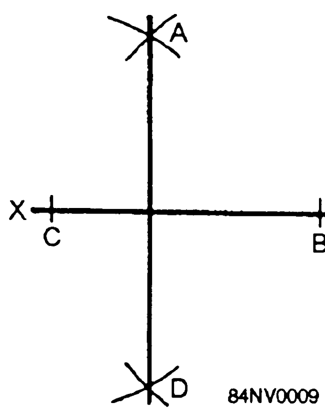


Figure 14-9.—Drawing a perpendicular to a given line from a given point.

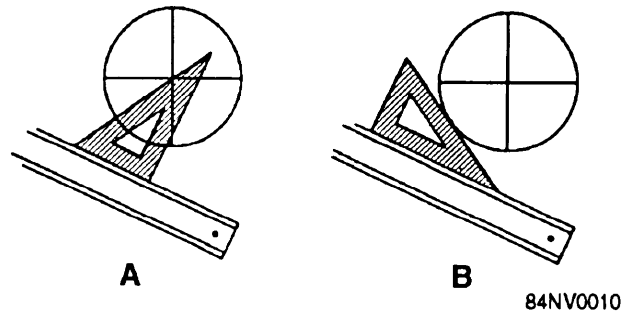


Figure 14-10.—Drawing a tangent to a circle at a given point.

1. Place a triangle against a straightedge, as shown in view A. The hypotenuse of the triangle should pass through the center of the circle and the point where the line is to be tangent to the circle.
2. Hold the straightedge firmly in place, and turn the triangle over.
3. Move the triangle until the hypotenuse passes through the point of tangency, and then draw the tangent, as shown in view B.

Drawing an Arc to a Line

You may find that when you draw an arc that ends in a straight line, you have a tendency to overdraw the arc (fig. 14-11). Use the following procedure and the steps shown in figure 14-12 to avoid this.

1. Use any given radius as the distance to set your dividers.
2. Set one point of the dividers at point A and strike tangent points at B and C (view A).
3. Without changing the dividers, place one point at B and strike an arc at D.

Figure 14-11.—Errors in drawing a line to the end of an arc.

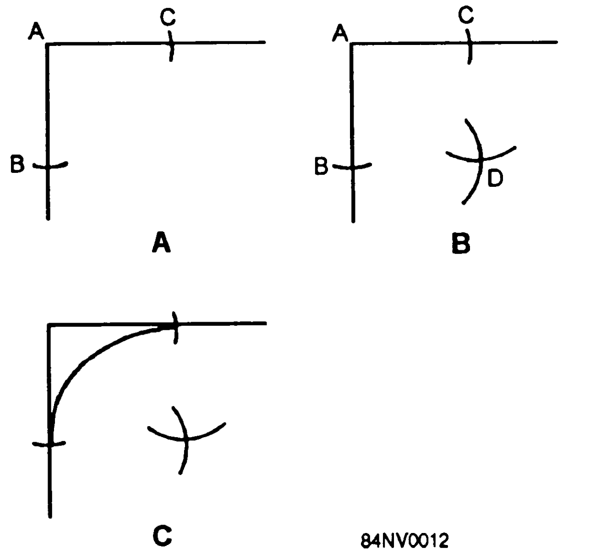


Figure 14-12.—Precaution to avoid overdrawing an arc that ends in a straight line.

4. Next, place the point at C and strike another arc intersecting the arc at D (view B).
5. Place one divider point where these two arcs intersect and strike an arc to the points of tangency (view C).

Drawing Arcs Tangent to Two Lines (Fillets and Rounds)

Small arcs tangent to two lines forming an inside comer are fillets. They must often be drawn after the straight lines have been drawn. Small arcs tangent to two lines forming an outside comer are rounds.

Use the following steps to draw a fillet or round when two lines form a right angle. Remember, look at figure 14-13 as you read these steps.

1. Adjust the dividers to the required radius.
2. Place one point of the dividers at the comer of the angle, and draw a short arc intersecting each straight line (view A). Intersection points of the arcs and the lines are the point of tangency.

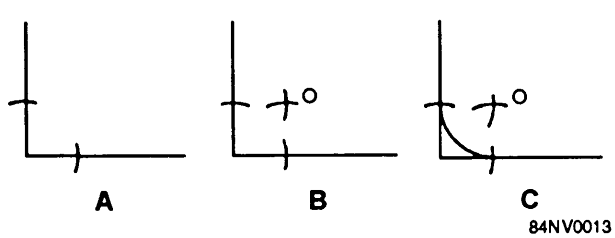


Figure 14-13.—Drawing a fillet or round to a right angle.

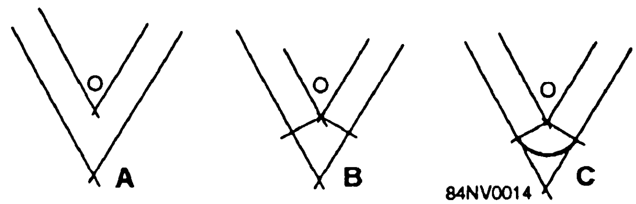


Figure 14-14.—Drawing a fillet or round to two lines that do not form a right angle.

3. Use the intersection points as alternate centers for the point of the dividers. Draw intersecting arcs inside the angle (view B).
4. Use this point of intersection (O) as the center for the point when you draw the fillet, as shown in view C.

Use the following steps to draw a fillet or round when the lines form an angle that is <u>not a</u> right angle. Look at figure 14-14 as you read these steps.

1. Draw lines inside the angle that are parallel to the first two lines. Draw them a distance of a given radius from the first two lines (view A). The intersection of these parallel lines will be the center of the fillet's arc.
2. Find the exact points of tangency, as shown in view B.
3. Now draw the fillet, using the intersection of the inside lines (point 0) as the center of the circle. Start at one point of tangency and stop when the arc touches the other point of tangency (view C).

Drawing Large Arcs Tangent to Smaller Arcs

Any of the methods of drawing fillets apply in laying out large circles or arcs tangent to other arcs. The trial-and-error method is shown in figure 14-15. In this figure, the arc of a large circle is tangent to two small circles or arcs. Points T and T´ are estimated as the points of tangency. Use them to find the intersecting arcs at point O. Point 0 is used as the center in drawing the arc from T to T´.

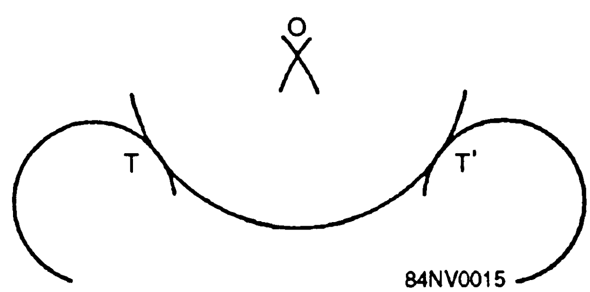


Figure 14-15.—Trial-and-error method of drawing a large arc tangent to two smaller arcs.

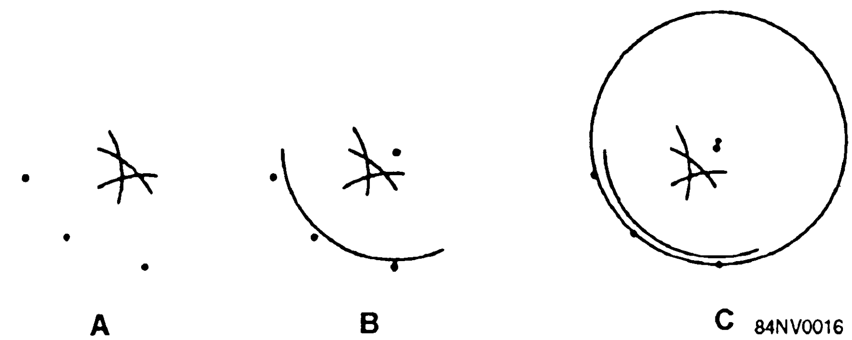


Figure 14-16.—Trial-and-error method of finding the center of a circle that passes through three given points.

The trial-and-error method also can be used in drawing a circle through three given points. In figure 14-16, view A, arcs with an equal radius have been drawn from each of the three points. You can see that they fail to have a common point of intersection and are, therefore, not at the proper center.

If the arcs from the two outer points intersect below the center point arc (view B), you know that the radius of the circle is larger. If the two outer points intersect above the center point arc, then the radius of the circle is smaller.

From this trial you can judge where the center will probably fall. Select a point (O) to use as the center in drawing your first trial arc. If this trial arc fails to pass through the three points perfectly (view B), move the center, as shown in view C.

This time you can judge the position of the center so accurately that the circle may be drawn through the points (view C).

Drawing a Reverse or Ogee Curve Tangent to Two Lines

The following steps tell you how to draw a reverse or ogee curve. Refer to figure 14-17 as you read this section.

1. Erect a perpendicular at point A and drop one at point B (view A).
2. Connect points A and B with a line (view B).
3. Assume a point (C) on this line through which the curve will pass. This point may be the midpoint of the line if equal arcs are desired.
4. Bisect AC and CB, as shown in view C. The intersection of these lines with the perpendiculars from points A and B are the centers of the required arcs. Complete the curve, as shown in view D.

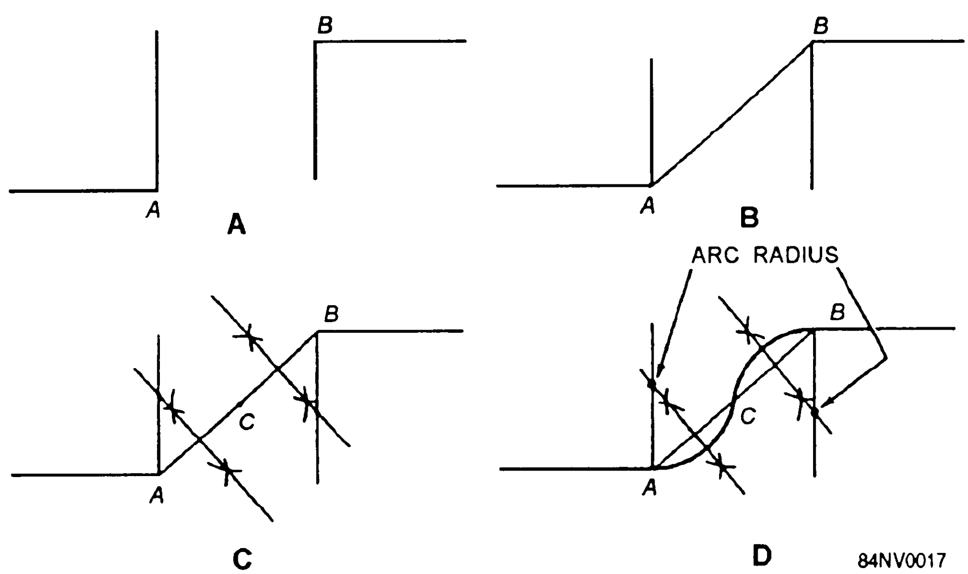


Figure 14-17.—Reverse or ogee curve.

DRAWING PLANE FIGURES

A plane has only two dimensions. Your layout is a plane. This section gives methods of construction for several plane figures.

DRAWING TRIANGLES WITH GIVEN LENGTH SIDES

Figure 14-18 shows the steps in drawing a triangle with given lengths for its sides. The lengths for the sides are shown in view A.

1. Draw one side of the triangle in the desired position as the base line (view B).
2. Adjust the dividers to the length of a second side. Using one end of the base line as a center for the point of the dividers, draw an arc (view B).
3. Adjust the dividers to the length of the third side. From the other end of the base line, draw another arc that intersects the first arc (view B).
4. Draw lines from the intersection point of these arcs to the ends of the base line. They are for the sides of the triangle (view C).

DRAWING EQUILATERAL, ISOSCELES, AND RIGHT TRIANGLES

An equilateral triangle has three equal sides. To draw this type of triangle, first draw one side as the base line. Then, use the length of that side as the radius to draw intersecting arcs from each end of the base line (fig. 14-19, view A).

An isosceles triangle has two equal sides. To draw an isosceles triangle, first draw the base. Then, draw intersecting arcs from each end of the base line. Use the length of one of the equal sides as the radius (fig. 14-19, view B).

A right triangle has a 90-degree angle. You can draw a right triangle by using the method for bisecting a line (refer to fig. 14-2). Draw a perpendicular from the end of a line (refer to fig. 14-8), or draw a perpendicular to a given line from a given point (refer to fig. 14-9).

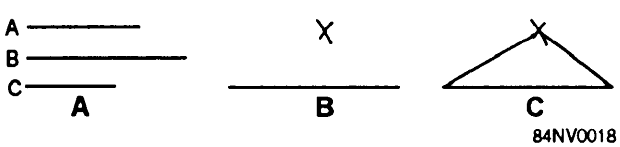


Figure 14-18.—Drawing a triangle with three given sides.

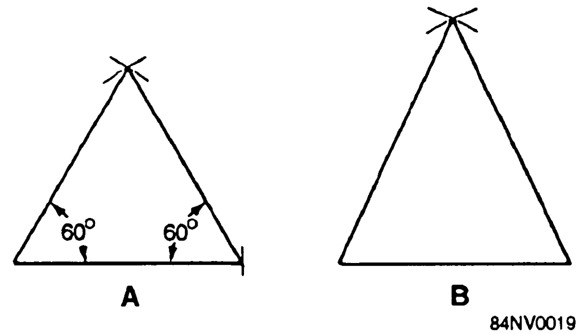


Figure 14-19.—Drawing triangular plane figures. A. An equilateral triangle. B. An isosceles triangle.

CONSTRUCTING A REGULAR PENTAGON WITHIN A CIRCLE

Look at figure 14-20. Here, you can see how to draw a pentagon. Refer to figure 14-20 as you read the following section.

1. Draw the diameter of the circle, shown as line AOB (view A).
2. Bisect radius OB of the circle (view B).
3. With D as a center and a radius equal to DC, strike arc CE (view C).
4. With C as a center, strike arc FG passing through point E (view D).
5. Distance CF or CG is equal to the length of one side of the pentagon. Mark off the other sides with the dividers (view E).

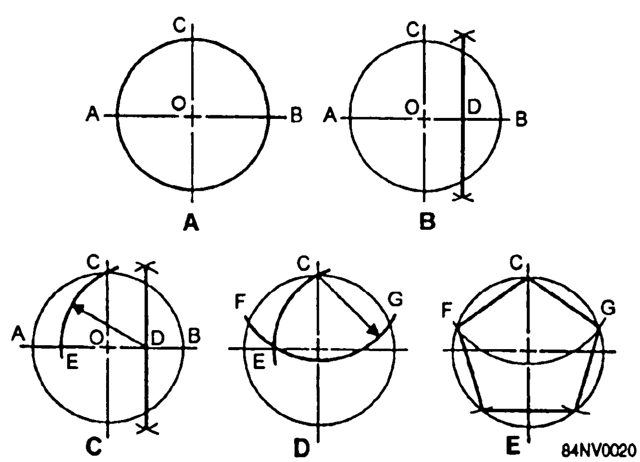


Figure 14-20.—Drawing a regular pentagon in a circle.

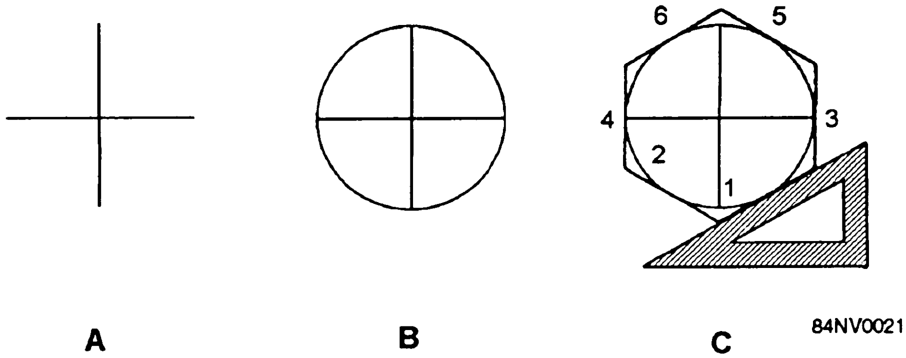


Figure 14-21.—Drawing a regular hexagon when the distance across flats is given.

DRAWING A REGULAR HEXAGON

Bolt heads and nuts are hexagonal forms (six sided) and are common figures in mechanical drawings. You can draw a regular hexagon if you are given the distance between opposite sides of a hexagon. The opposite sides are the *short distance* or *distance across the flats.* To draw the hexagon, use the following steps. Refer to figure 14-21 as you read this section.

1. Draw a horizontal line and a vertical line. Draw each as long as a given distance. They intersect at right angles to each other (view A).
2. With these lines as diameters and their intersection as the center for the point of the dividers, draw a circle as shown in view B.
3. Using the 30- to 60-degree triangle resting on a T-square or straightedge base, draw lines tangent to the circle in the order shown in view C.

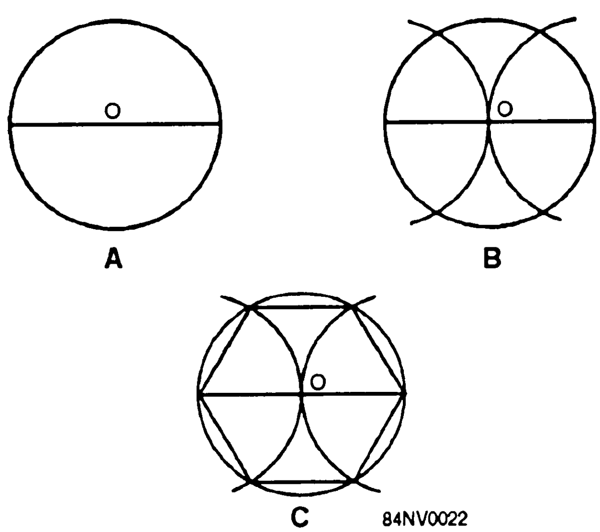


Figure 14-22.—Drawing a regular hexagon when the distance across corners is given.

If you are given the distance between opposite comers of a hexagon, called the *distance across comers* or the long *diameter,* use the method shown in figure 14-22.

1. Draw a circle with the long diameter as the circle diameter (view A).
2. Using the same radius as you used to draw the circle, draw arcs with the ends of the diameter as centers (view B).
3. Draw lines from the points where the arcs intersect the circle to those where the diameter touches the circle (view C).

DRAWING A REGULAR OCTAGON (AN EIGHT-SIDED FIGURE)

As you read this section, refer to figure 14-23. If you are given the distance between opposite sides of an octagon, you can use the following method to draw a regular octagon.

1. Use the given distance as the side dimension in drawing a square (view A).
2. Draw the diagonals of the square.
3. Adjust the dividers to a radius equal to one-half the length of a diagonal.

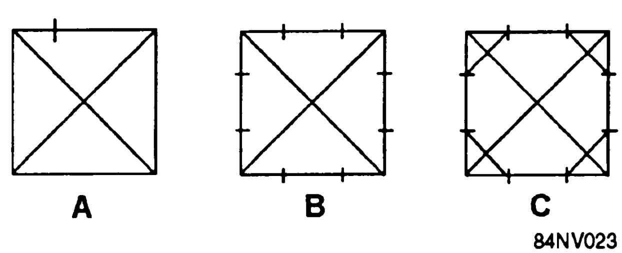


Figure 14-23.—Drawing a regular octagon when the distance between sides is given.

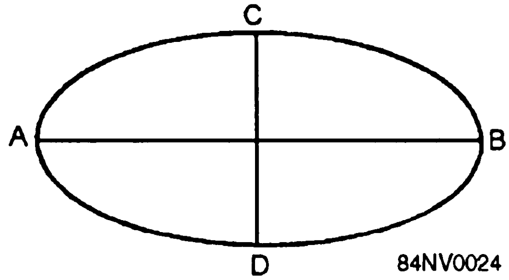


Figure 14-24.—An ellipse with major axis AB and minor axis CD.

4. Place the point of the dividers on each comer and draw arcs intersecting the sides of the square (view B).
5. Draw lines connecting the intersecting points and form a regular octagon (view C).

DRAWING AN ELLIPSE

The ellipse is a difficult figure to draw. There are several ways you can use to draw it. Normally, you are given the length of the major and minor axes of the ellipse (fig. 14-24).

Using a Compass to Draw an Ellipse

As you read this section, refer to figure 14-25. An ellipse that is not accurate but gives a good visual effect may be drawn, using a compass, as follows:

1. Draw the major and minor axes.
2. Draw a line connecting one end of the major axis and one end of the minor axis (view A).
3. Using a radius equal to half the major axis and with C as the center, lay off OE on OB (view B).
4. Using a radius equal to EB, lay off CF on CB (view C).
5. Bisect line FB as shown in view D. Extend the bisecting line to intersect AB at X and CD at Y.
6. Using a radius equal to XB, lay off AX´. Using a radius equal to DY, lay off CY´ (view D).
7. Using radii XB and X´A, draw the arcs, as shown in view E.
8. Using radii YC and Y´D, draw the side arcs, as shown in view F.

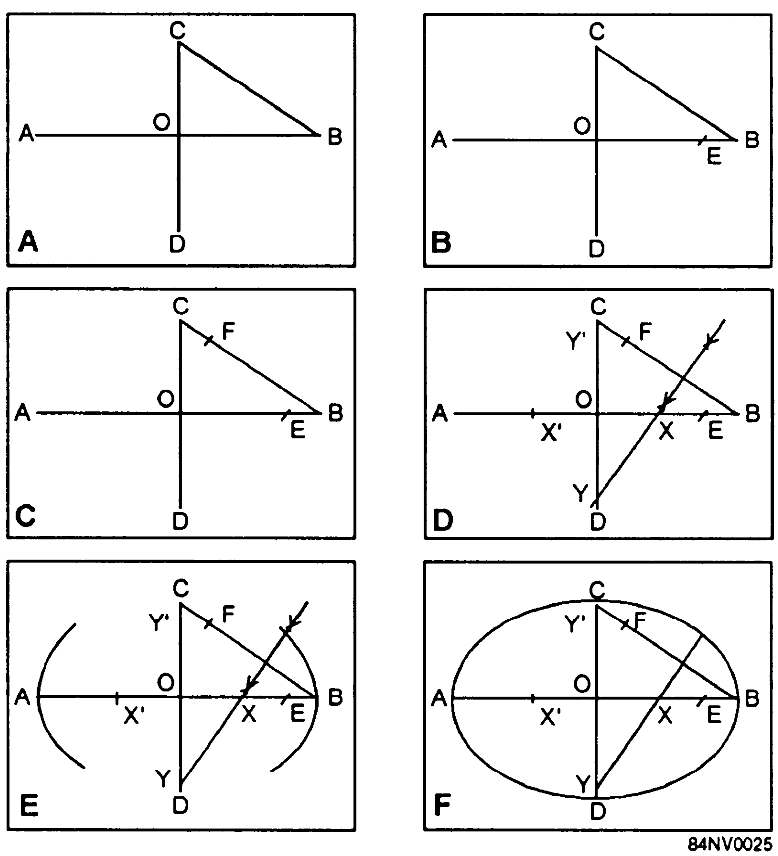


Figure 14-25.—Drawing an ellipse.

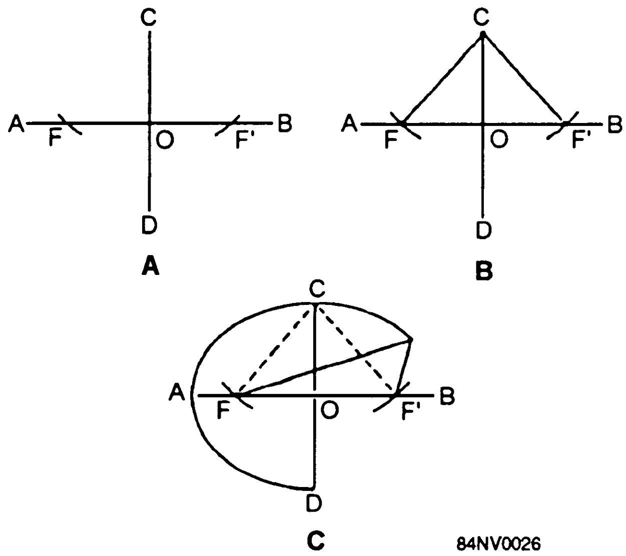


Figure 14-26.—Drawing an ellipse using a pin and string.

Pin-and-String Method

The easiest method of drawing a large ellipse is the pin-and-string method. To use this method, refer to figure 14-26 and use the following steps:

1. Draw the major and minor axes.
2. Set the dividers to one-half the length of the major axis. Using one end of the minor axis as a center, draw arcs intersecting the major axis. Points F and F´ are the foci of the ellipse (view 4 .
3. Drive pins at the foci and at one end of the minor axis. Tie a cord around the three pins, as shown in view B.
4. Remove the pin at the end of the minor axis, and place a pencil or pen inside the loop. Keep the string taut and draw the line of the ellipse.

Trammel Method

An ellipse may also be drawn by the trammel method. You will need your straightedge. On the straight edge of a strip of material, mark half the distance of the major axis, AO (fig. 14-27, view A). Then, mark half the distance of the minor axis, CO. Draw the major and minor axes on the drawing sheet. Move the straightedge, keeping point A on the minor axis and point C on the major axis. Using point 0 as the guide, draw the ellipse as shown in view B.

Concentric-Circle Method

The concentriccircle method of drawing an ellipse is the most accurate of the methods discussed in this section. However, you must be able to handle your instruments accurately. As you read this section, refer to figure 14-28.

1. Draw the major and minor axes.
2. With the intersection as a center, draw a circle that has the major axis as a diameter. Then, draw another circle with the minor axis as the diameter (view A).
3. Draw several radii from the center to the arc of the larger circle (view B).
4. Wherever these lines cut the smaller circle, draw short horizontal lines outward from the arc of that circle.
5. Wherever the radii touch the larger circle, draw short vertical lines to intersect the short horizontal lines (view C). The points where these short horizontal and vertical lines intersect define the ellipse.
6. Use the French curve and draw the ellipse from these plotted points (view D). The French curve

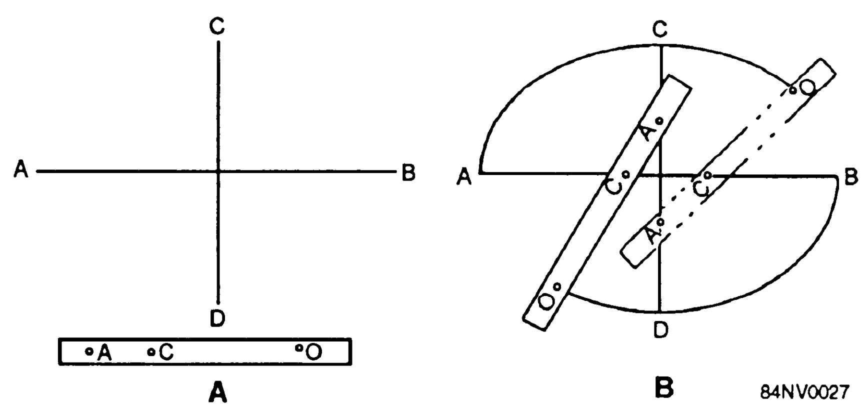


Figure 14-27.—Drawing an ellipse using the trammel method.

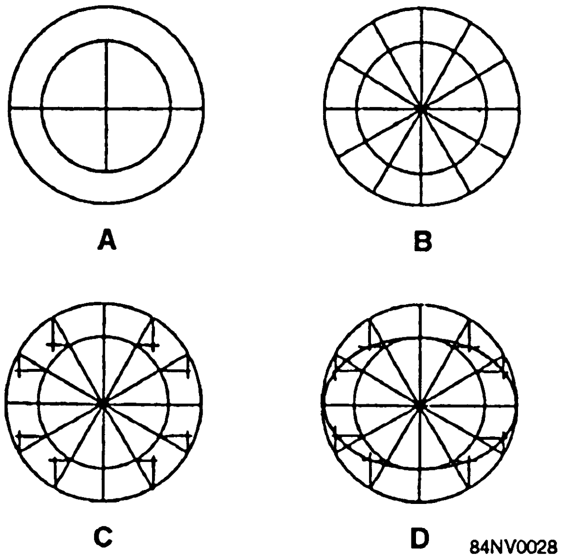


Figure 14-28.—Drawing an ellipse using the two-circle method.

is an instrument used to draw smooth irregular curves.

DRAWING SPIRALS AND INVOLUTES

A spiral or involute is a constantly changing curve that winds, coils, or circles around a center point. For a practical example, the main spring in your watch is a spiral. This section gives methods of construction for common spirals.

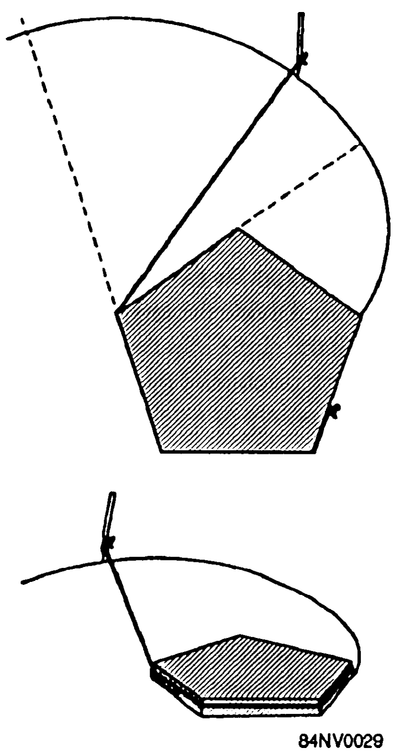


Figure 14-29.—Drawing the involute of a pentagon using pin and string.

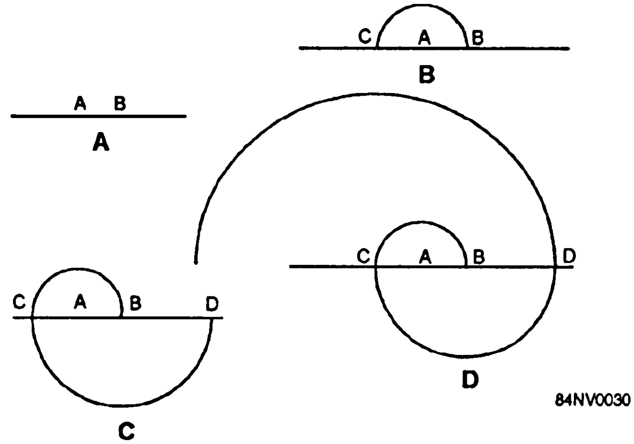


Figure 14-30.—Drawing the involute of a line.

An involute is the curve that might be traced by a point on a cord that is being unwound from a line, a triangle, a square, or other geometric figure. Figure 14-29 shows the pin-and-string method of drawing the involute of a pentagon.

Drawing the Involute of a Line

Look at figure 1430. To draw the involute of a line, extend line AB (view A). Using length AB as a radius and A as a center, draw a semicircle (view B). Then, using BC as the radius and B as the center, draw a second semicircle, continuing the curve as shown in view C. Then, with CD as the radius and C as the center, draw the next arc as shown in view D. Proceed until the curve is the desired size.

Drawing the Involute of a Triangle

As you draw the involute of a triangle, refer to figure 14-3 1. Extend the sides of the triangle (view A).

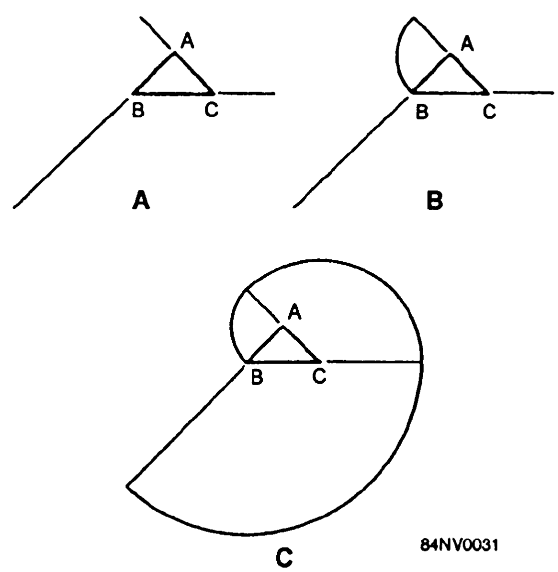


Figure 14-31.—Drawing the involute of a triangle.

Use one side of AB as a radius and A as the center. Draw an arc from B to the extension of side AC, as shown in view B. Next, measure a radius the length of AC plus its extension. With C as the center, draw an arc to the extension of side BC. With BC plus its extension as the radius and B as the center, draw an arc to the extension of side AB, as shown in view C. Continue in this manner until the figure is the desired size.

Drawing the Involute of a Circle

Consider the circle as a polygon with many sides. Divide the circumference of the circle into several equal segments (fig. 14-32, view A). Then, draw tangents from each segment (view B). With the cord of a segment as a radius, draw an arc from one segment to intersect the tangent of the next segment, as shown in view B. With the intersection point on this tangent to the point of tangency as a radius, draw an arc to intersect the next tangent (view C). Continue until the figure is the required size.

Drawing a Spiral of Archimedes

The spiral is generated by a point moving around a fixed point, its distance increasing uniformly with the angle. To draw a spiral that makes one turn in a given circle, divide the circle into several equal segments (fig. 14-33, view A). Then, divide the radius of a circle into the same number of parts, and number them from the center outward (view A). Using the center of the circle as a center, draw an arc from each of the numbered segments that intersect the corresponding numbered divisions on the radius (view B). These intersections are the points of the curve (view C).

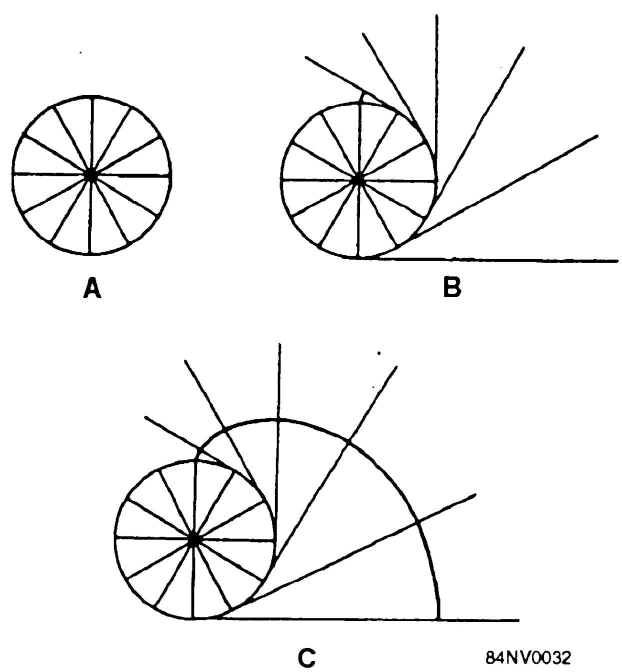


Figure 14-32.—Drawing the involute of a circle.

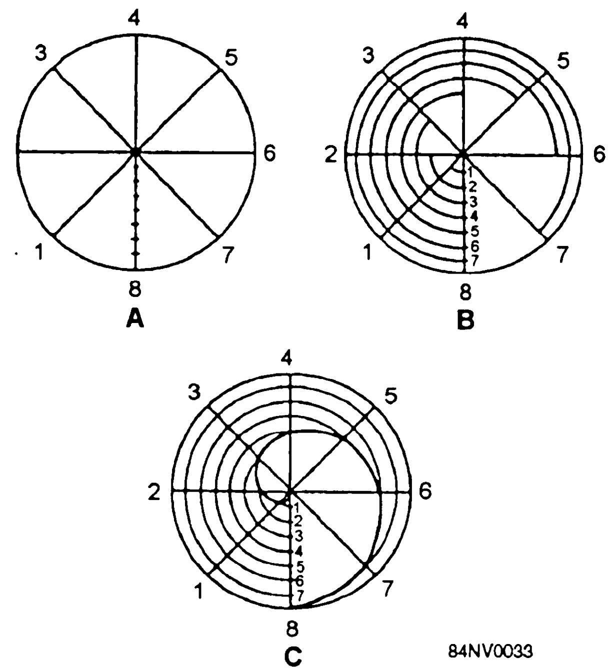


Figure 14-33.—Drawing the spiral of Archimedes.

Drawing the Helix

Consider the helix (fig. 14-34), a curve that is generated by a point moving uniformly along a straight line that revolves around an axis. If the line moves parallel to the axis, it will generate a cylindrical helix. If it moves at an angle to the. axis, it will generate a conical helix. The lead of a helix is the distance along the axis to which the point advances in one revolution.

To draw a helix, draw two views of the cylinder, as shown in view A. Divide the lead into an equal number of parts. Divide the circle into the same number of parts (view B). The intersection of the lines from these points (view C) are the points of a cylindrical helix.

AREAS AND VOLUMES

You must be able to calculate the amount of material needed to manufacture or repair many different items used throughout the Navy. You must also be able to determine the weight of the finished product to calculate the approximate weight of an object. To do this, you must have a knowledge of geometry and be able to determine areas and volumes of geometric shapes and figures.

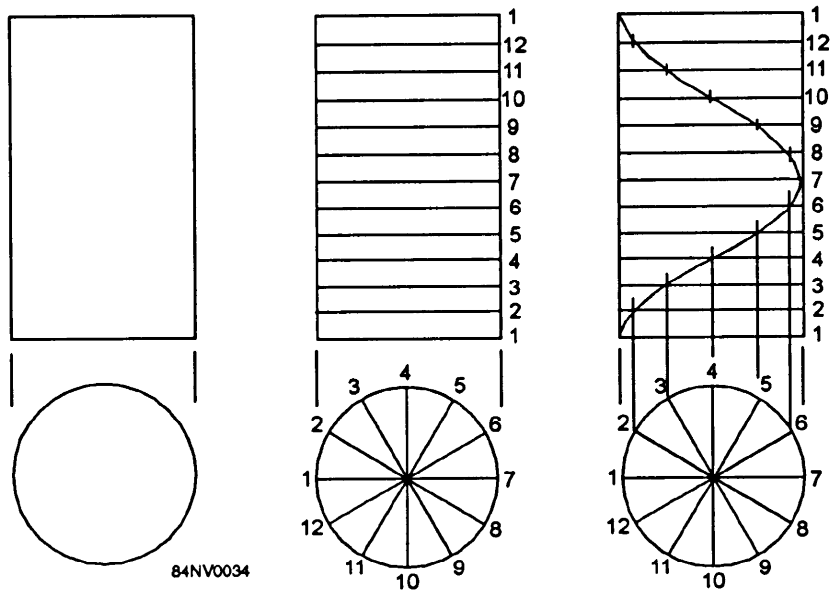


Figure 14-34.—Drawing a helix.

Area is the extent of a surface bounded by two dimensions, such as length and width. The unit of measure showing area is the square, such as square inches, square feet, and square yards.

Volume is the extent of an object bounded by three dimensions, such as length, width, and height. The unit of measure showing volume is the cube, such as cubic inches or cubic feet.

To find the area (A) of the rectangle shown in figure 14-35, you must multiply the length (L) by the width (W) or A = LW. Since L = 8 inches and W = 5 inches, A = 8 x 5 = 40 square inches.

To find the volume (V) of the cube shown in figure 14-36, you must multiply length (L) times width (W) times height (H), or V = LWH. Since L = 8 inches, W = 5 inches, and H = 7 inches, $V = 8 \times 5 \times 7 = 280$ cubic inches.

Many of the geometric figures you will be concerned with are shown in figure 14-37. With each figure is the formula and some examples of problems for calculating area and volume for that particular figure.

When values are enclosed in parentheses ( ), brackets [ ], or braces { }, they are grouped. Some equations contain a group within a group. An example of this is the formula for finding the area of a trapezium where

A = 1/2[a(e + d) + bd + ce].

In this formula you have parentheses and brackets. Parentheses can be enclosed in braces, and braces can

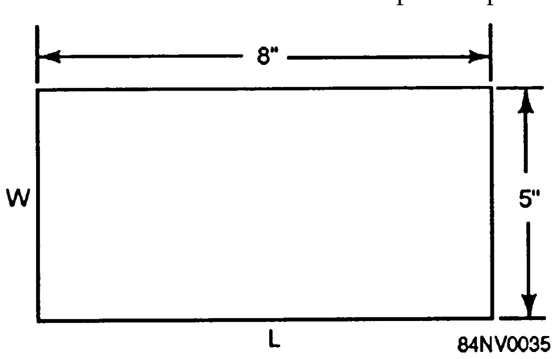


Figure 14-35.—Two-dimensional view.

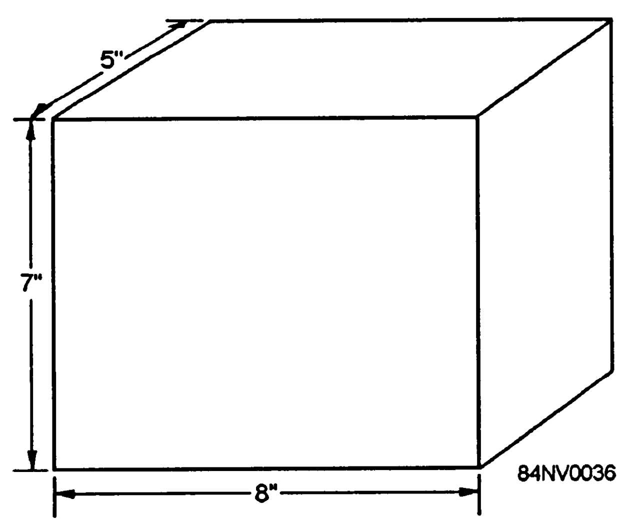
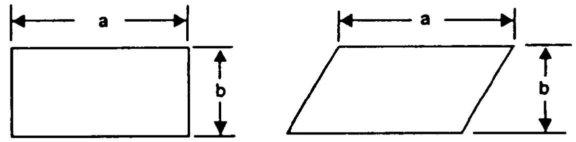


Figure 14-36.—Three-dimensional view.

Rectangle and Parallelogram

Area = ab



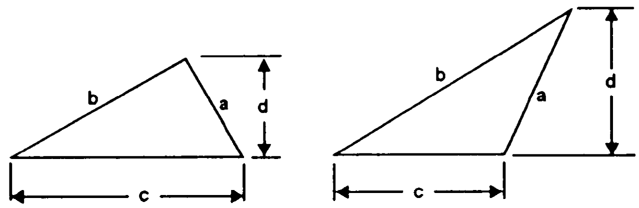
Triangle

Area = ½ cd.

Example: d = 5"

c = 6"

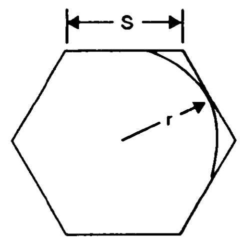
Then, ½ × 5" × 6" = 15 sq. in.



Regular Polygons

n = Number of sides, s = Length of one side, r = Inside radius

Area = ½ nsr



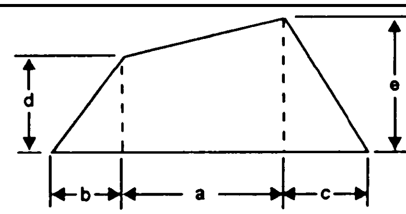
Number of Sides	Area
5	1.72047 s^2 = 3.63273 r^2
6	2.59809 s^2 = 3.46408 r^2
7	3.63395 s^2 = 3.37099 r^2
8	4.82847 s^2 = 3.31368 r^2
9	6.18181 s^2 = 3.27574 r^2
10	7.69416 s^2 = 3.24922 r^2
11	9.36570 s^2 = 3.22987 r^2
12	11.19616 s^2 = 3.21539 r^2

Trapezium

Area = ½ [a (e + d) + bd + ce]

Example: a = 10", b = 3", c = 5", d = 6", e = 8"

Area = ½ [10 (8 + 6) + (3 × 6) + (5 × 8)] = 99 sq. in.



Square

The diagonal of a square = A X 1.414

The side of a square inscribed in a given circle is B X 0.707.

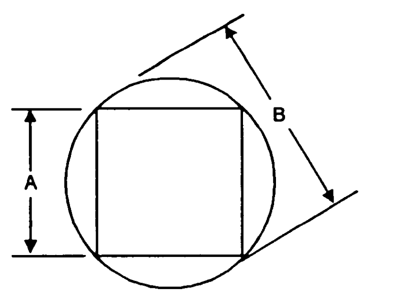


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Figure 14-37.—Areas and volumes for calculating weights of castings.

be enclosed in brackets. The reverse is not true. The values enclosed by parentheses must be calculated before the values within brackets. As an example, find the area of a trapezium using the formula and values shown in figure 14-37.

A= 1/2[a(e + d) + bd + ce]

A= 1/2[10(8 + 6) + 3 x 6 + 5 × 8]

A= 1/2[10(14) + 18 + 40]

A= 1/2[140+18 + 40]

Circle

θ (the Greek letter Theta) = angle included between radii

π (pi) = 3.1416, D = Diameter, R = Radius, C = Chord.

h = Height of Arc, L = Length of Arc.

Circumference $= \pi D = 2\pi R = 2\sqrt{\pi \times \text{Area}}$

Diameter $= 2R =$ Circumference $\div \pi = 2\sqrt{\frac{\text{Area}}{\pi}}$

Radius $= \frac{1}{2}D =$ Circumference $\div 2\pi = \sqrt{\frac{\text{Area}}{\pi}}$

Radius $= \dfrac{\left(\frac{C}{2}\right)^2 + h^2}{2h}$

Area $= \frac{1}{4}\pi D^2 = 0.7854\, D^2 = \pi R^2$

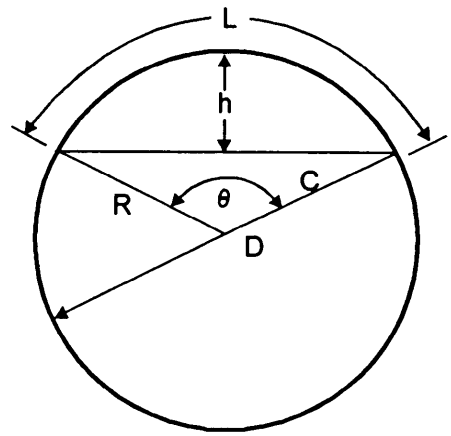
Chord $= 2\sqrt{h\,(D-h)} = 2R \times \text{sine } \frac{1}{2}\theta$

Height of Arc, $h = R - \sqrt{R^2 - \left(\frac{C}{2}\right)^2}$

Length of Arc, $L = \frac{\theta}{360} \times 2\pi R = 0.0174533\, R\theta$

$\frac{1}{2}\theta$ (in degrees) $= 28.6479 \frac{L}{R}$

Sine $\frac{1}{2}\theta = \frac{C}{2} \div R$



Sector of a Circle

Area $= \frac{1}{2}$ LR

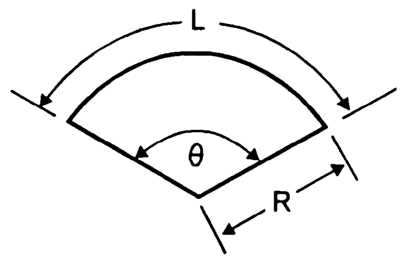
Example: L = 10.472", R = 5"

Area $= \frac{10.472}{2} \times 5 = 26.180$ sq. in.

or Area $= \pi R^2 \times \frac{\theta}{360} = 0.0087266\, R^2\theta$

Example: R = 5", $\theta = 120°$

Area $= 3.1416 \times 5^2 \times \frac{120}{360} = 26.180$ sq. in.



Segment of a Circle

Area $= \pi R^2 \times \frac{\theta}{360} - \frac{C\,(R-h)}{2}$

Example: R = 5", $\theta = 120°$, C = 8.66", h = 2.5"

Area $= 3.1416 \times 5^2 \times \frac{120}{360} - \frac{8.66\,(5-2.5)}{2} = 15.355$ sq. in.

Length of arc $L = 0.0174533\, R\theta$

Area $= \frac{1}{2}\left[LR - C(R-h)\right]$

Example: R = 5", C = 8.66", h =- 2.5", $\theta = 120°$

$L = 0.0174533 \times 5 \times 120 = 10.472"$

Area $= \frac{1}{2}\left[(10.472 \times 5) - 8.66\,(5-2.5)\right] = 15.355$ sq. in.

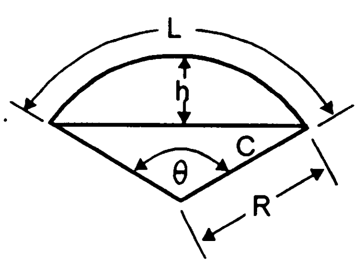


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Figure 14-37.—Areas and volumes for calculating weights of castings—Continued.

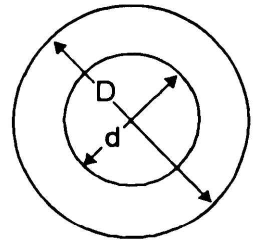
A = 1/2[198]

A= [99]

After substituting numerical values for the letter symbols, add *e* + *d,* since they are enclosed within parentheses. There are no symbols between a and the first parenthesis. This means that a must be multiplied by the sum of *e* + *d,* which results in a product of 140. Next multiply *bd* and *ce.* This results in products of 18 and 40. When these products are added to 140, you

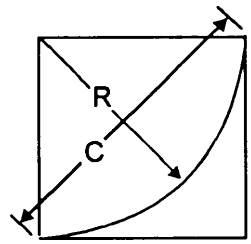
Circular Ring

Area = $0.7854 (D^2 - d^2)$. or $0.7854 (D - d) (D + d)$
Example: D = 10", d = 3"
Area = $0.7854 (10^2 - 3^2) = 71.4714$ sq. in.



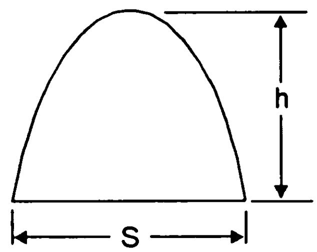
Spandrel

Area = $0.2146 R^2 = 0.1073 C^2$
Example: R = 3
Area = $0.2146 \times 3^2 = 1.9314$



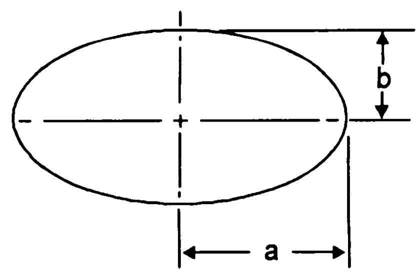
Parabolic Segment

Area = $\frac{2}{3}sh$
Example: s = 3, h = 4
Area = $\frac{2}{3} \times 3 \times 4 = 8$



Ellipse

Area = $\pi ab = 3.1416\ ab$
Example: a = 3, b = 4
Area = $3.1416 \times 3 \times 4 = 37.6992$



Irregular Figures

Area may be found as follows:
Divide the figure into equal spaces
as shown by the lines in the figure.

(1) Add lengths of dotted lines.
(2) Divide sum by number of spaces.
(3) Multiply result by A.

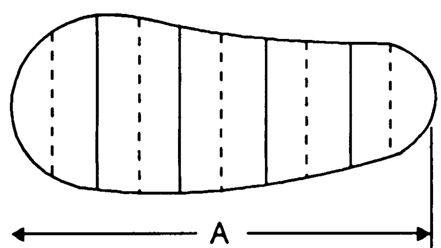


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Figure 14-37.—Areas and volumes for calculating weights of castings—Continued.

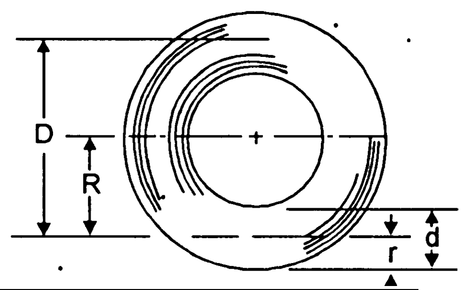
have a value of 198. This value is now multiplied by l/2, resulting in a product of 99. Since all values are in inches, the area is 99 square inches.

PRINCIPLES OF SURFACE DEVELOPMENT

A surface has two dimensions—length and width. It is bounded by lines that are either straight or curved.

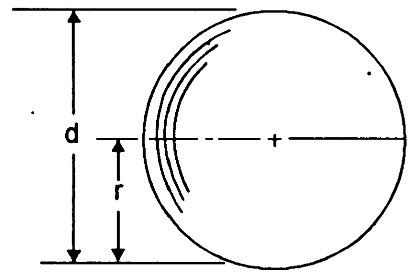
Ring of Circular Cross Section

Area of surface $= 4\pi^2 Rr = 39.4784\ Rr$
Area of surface $= \pi^2 Dd = 9.8696\ Dd$
Volume $= 2\pi^2 Rr^2 = 19.7392\ Rr^2$
Volume $= \frac{1}{4}\pi^2 Dd^2 = 2.4674\ Dd^2$



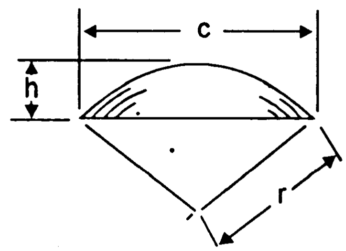
Sphere

Surface $= 4\pi r^2 = 12.5664\ r^2 = \pi d^2$
Volume $= \frac{4}{3}\pi r^3 = 4.1888\ r^3$
Volume $= \frac{1}{6}\pi d^3 = 0.5236\ d^3$



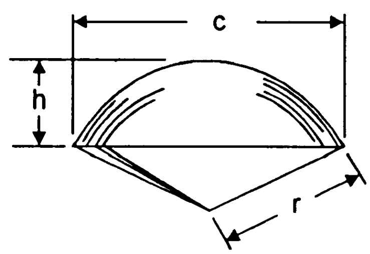
Segment of a Sphere

Spherical surface $= 2\pi rh = \frac{1}{4}(c^2 + 4h^2) = 0.7854\ (c^2 + 4h^2)$
Total surface $= \frac{1}{4}\pi(c^2 + 8rh) = 0.7854\ (c^2 + 8rh)$
Volume $= \frac{1}{3}\pi h^2(3r - h) = 1.0472\ h^2\ (3r - h)$
or
Volume $= \frac{1}{24}\pi h\ (3c^2 + 4h^2) = 0.1309\ h\ (3c^2 + 4h^2)$



Sector of a Sphere

Total surface $= \frac{1}{2}\pi r\ (4h + c) = 1.5708\ r\ (4h + c)$
Volume $= \frac{2}{3}\pi r^2 h = 2.0944\ r^2 h$



Cylinder

Cylindrical surface $= \pi dh = 2\pi rh = 6.2832\ rh$
Total surface $= 2\pi r\ (r + h) = 6.2832\ r\ (r + h)$
Volume $= \pi r^2 h = \frac{1}{4}\pi d^2 h = 0.7854\ d^2 h$

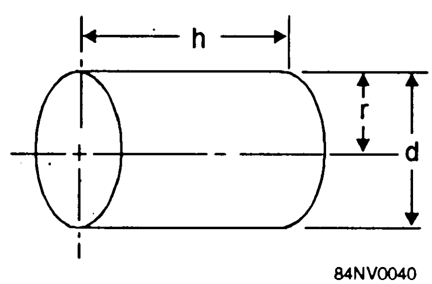
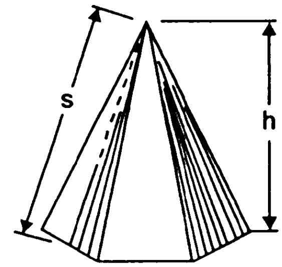


Figure 14-37.—Areas and volumes for calculating weights of castings—Continued.

The surface itself may be plane or flat. It could be plane-curved, such as the peripheral surface of a cylinder; warped, like the surface of a screw thread; or double-curved, like the surface of a sphere. A plane-curved surface can be unrolled and laid out flat. This is called developing the surface, A warped surface or double-curved surface can only be developed approximately.

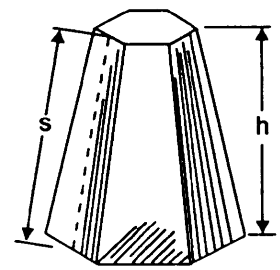
Pyramid

A = Area of base
P = Perimeter of base
Lateral area = $\frac{1}{2}$ Ps
Volume = $\frac{1}{3}$Ah



Frustum of a Pyramid

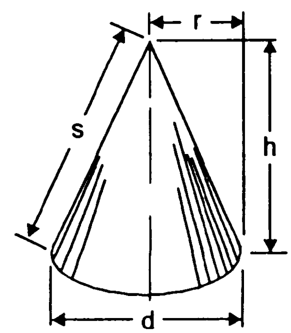
A = Area of base
a = Area of top
m = Area of midsection
P = Perimeter of base
p = Perimeter of top
Lateral area = $\frac{1}{2}s\ (P + p)$
Volume = $\frac{1}{3}h\ (a + A + \sqrt{aA})$
Volume = $\frac{1}{6}h\ (A + a + 4\,m)$



Cone

Conical area + $\pi rs = \pi r \sqrt{r^2 + h^2}$

Volume = $\frac{1}{3}\pi r^2 h = 1.0472\ r^2 h = 0.2618\ d^2 h$



Frustum of a Cone

A = Area of base
a = Area of top
m = Arca of midscction
R = D ÷ 2; r = d ÷ 2
Arca of conical surfacc = $\frac{1}{2}\pi s\ (D + d) = 1.5708\,s\,(D + d)$
Volume = $\frac{1}{3}h\ (R^2 + Rr + r^2) = 1.0472\,h\ (R^2 + Rr + Rr + r^2)$
Volume = $\frac{1}{12}h\ (D^2 + Dd + d^2) = 0.2618\,h\ (D^2 + Dd + d^2)$
Volume = $\frac{1}{3}h\ (a + A + \sqrt{aA}) = \frac{1}{6}h\ (a + A + 4\,m)$

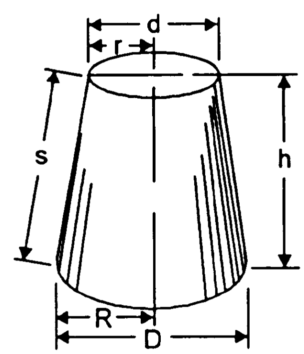


Figure 14-37.—Areas and volumes for calculating weights of castings—Continued.

In figure 14-38, several three-dimensional figures are shown. Try to form a mental picture of how these figures would look if they were unfolded or unrolled and laid out in a flat plane. The polyhedrons, of course, would be merely a system of connected squares, triangles, or other polygons. A cylinder with parallel ends would unroll into a parallelogram. A cone would unroll into a section of a circle. However, warped surfaces cannot lie flat. Double-curved surfaces present a similar problem.

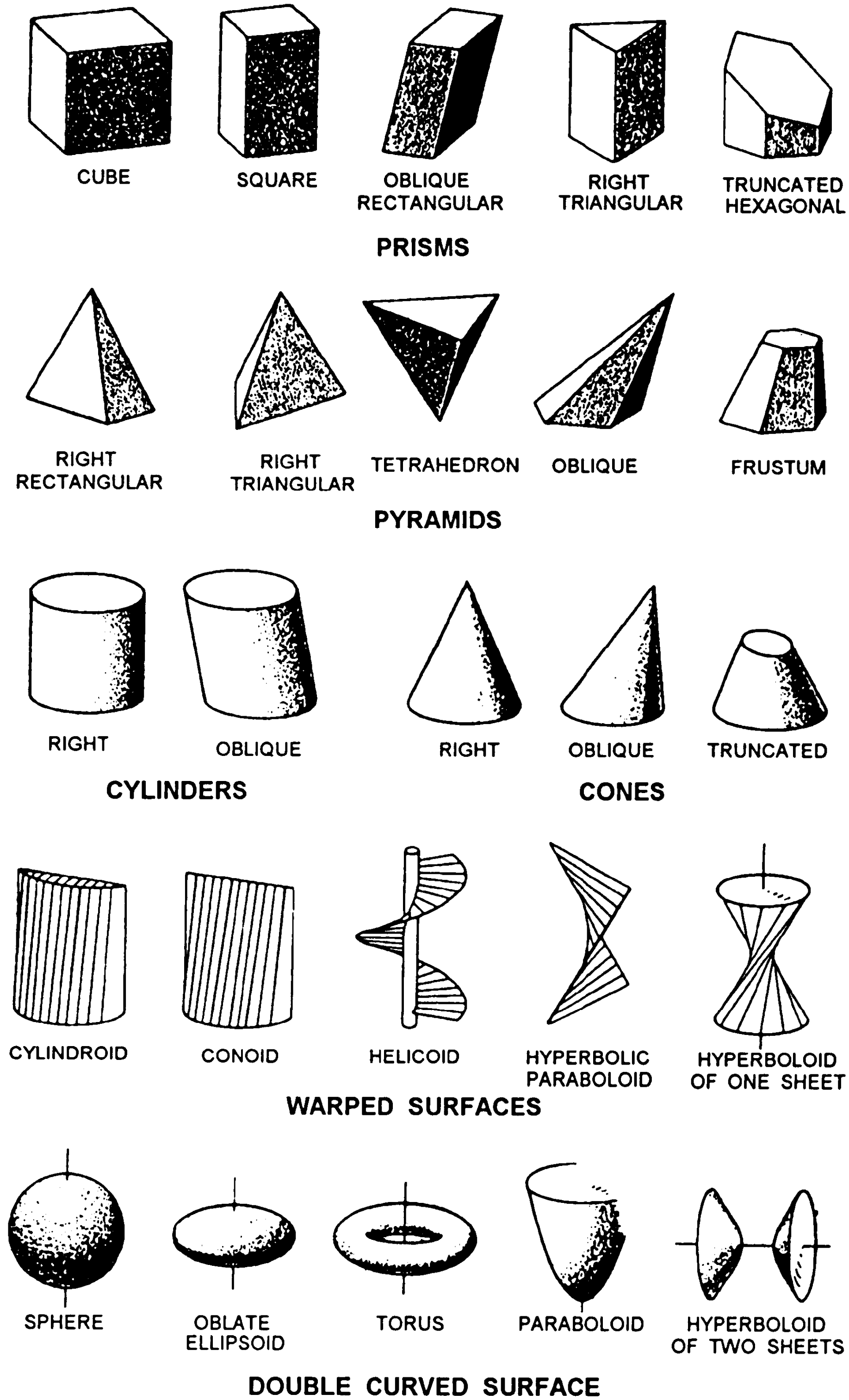


Figure 14-38.—Three-dimensional shapes.

The three principal methods of developing the surface of three-dimensional objects are parallel development, radial development, and triangulation. Parallel development is for surfaces such as prisms or

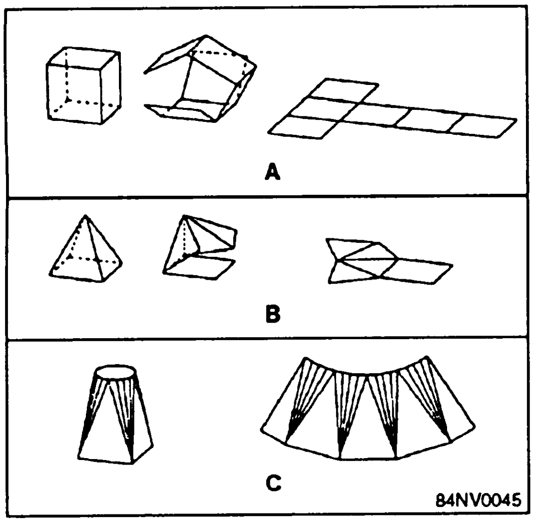


Figure 14-39.—Surface development. A. Parallel development. B. Radial development. C. Development by triangulation.

cylinders (fig. 14-39, view A). Radial development is for surfaces such as cones and pyramids (view B). Triangulation is for surfaces that do not lend themselves to either of the other two methods (view C).

Double-curved surfaces, such as a sphere, may be developed approximately by the same methods as those used for map projecting. A sphere can be cut into horizontal sections or zones that may be considered and developed as frustrums of cones (fig. 14-40, view A).

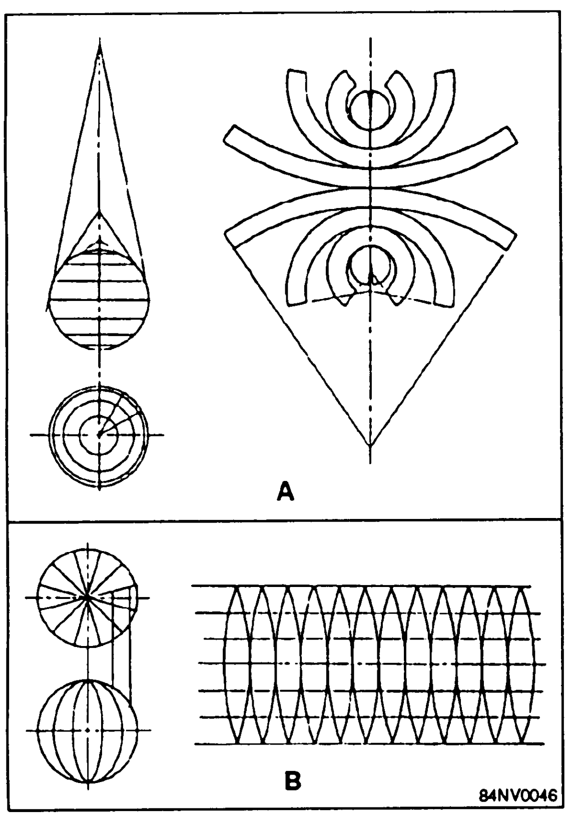


Figure 14-40.—Development of double-curved surfaces.

A sphere also can be cut into equal meridian sections called lunes, and these developed as if they were sections of cylinders (view B).

PARALLEL DEVELOPMENT

The surfaces of prisms and cylinders are parallel elements or elements that can be treated as parallel elements. Figure 14-41 shows the steps in developing a rectangular prism. You should refer to it as you read the following section.

1. To determine the length of all the edges of the prism, draw the front and top views in orthographic projection (view A).
2. Draw the development to one side of the front view so dimensions of vertical elements on that view can be projected to the development (view B).
3. Transfer the dimensions of other elements from the top view (view C). Mark all bend lines with crosses near their ends to distinguish them from outlines.
4. To check the drawing, measure the edges that are to join (view D). Such edges must correspond exactly.

Figure 14-42 shows the following steps in the development of a truncated hexagonal prism:

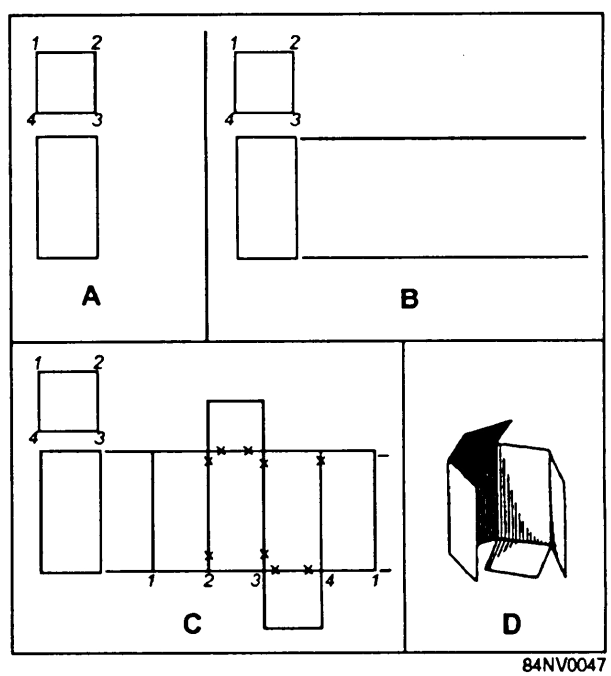


Figure 14-41.—Parallel development of a rectangular plane.

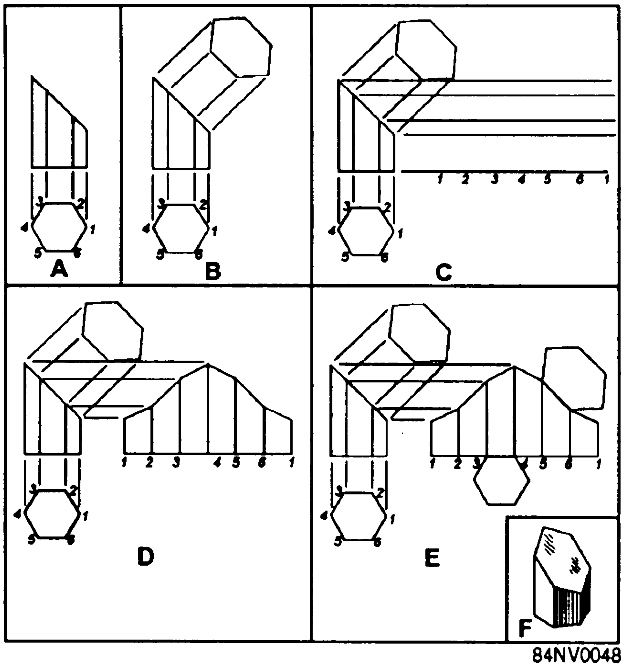


Figure 14-42.—Development of a truncated hexagonal prism.

1. Draw a front view and a bottom view of the prism in orthographic projection (view A).
2. Draw an auxiliary view (view B) since the true shape of the slanting plane and the length of the lines of its edges are not shown in these views. Note that drawing the entire prism in the auxiliary view is not necessary. Only the dimensions of the plane surface are required.
3. Project the lines of the front view horizontally as the first step in constructing the development (view C).
4. Number the points of intersection of planes on the bottom view. Mark off line segments of the same length on the base line of the development.
5. Erect vertical lines from these numbered points to intersect the lines projected from the front view of the prism (view D). These intersections mark the comers of the prism.
6. Connect the intersection points with straight lines.
7. Draw the bottom of the prism attached to one of the sides at the base line. Draw the slanting plane at the top of the prism (view E).
8. Check all edge measurements to be joined, as shown in the pictorial drawing (view F), to be sure they will coincide exactly.

The truncated cylinder is a prism with an infinite number of sides. The number of sides must be limited when developing a cylinder. However, the greater the number of sides, the more accurate the development. The following steps for the development of a truncated cylinder are shown in figure 14-43.

1. To develop one-half of a two-piece elbow, first draw a front and bottom view of that piece in orthographic projection (view A). Since the elbow does not require an end piece, you do not need to draw an auxiliary view showing the true shape of the ellipse formed by the cutting plane at the top of the cylinder.
2. Divide half the circumference of the circle into several equal parts. The parts should be small enough so a straight line drawn between division points will approximate the length of the arc. Project lines from these points to the front view (view B). The resulting parallel lines on the front view are called elements.

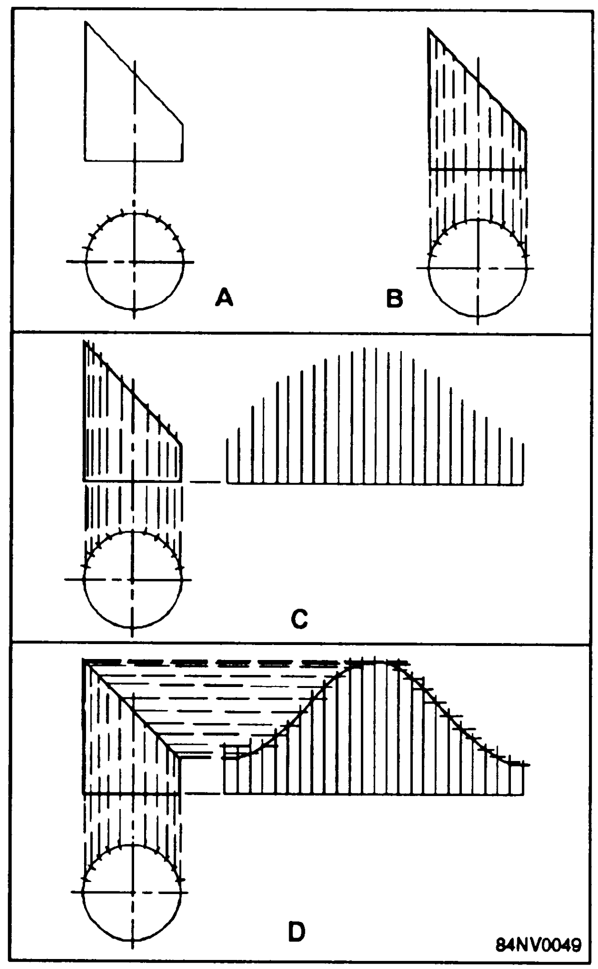


Figure 14-43.—Development of a truncated cylinder.

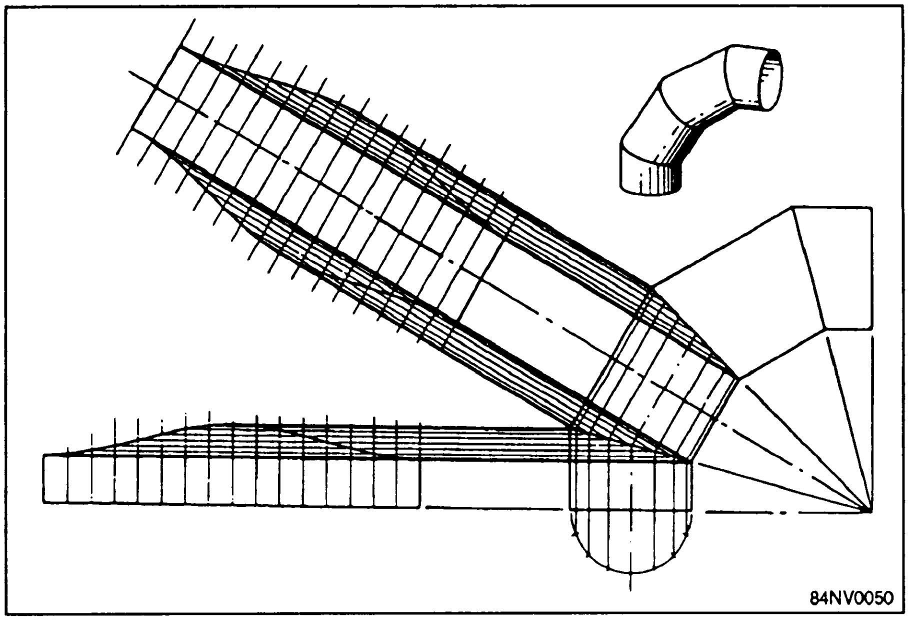


Figure 14-44.—Development for a four-piece elbow.

3. Lay off the base line, called the stretch-out line, of the development. The length of this line can be calculated as π times the diameter of the cylinder (3.14 × D).
4. Divide the stretch-out line into twice the number of equal parts as the number on the half circle of the orthographic view (view C).
5. Erect perpendiculars at each point, as shown in view C.
6. Using a T-square, project the lengths of the elements on the front view to the development (view D).
7. Using a French curve, join the resulting points of intersection in a smooth curve.

When the two pieces of the elbow are the same, you only need to make one drawing.

When a four-piece elbow is to be drawn, follow the same steps to produce as many developments as may be required. The orthographic view may be drawn of the whole elbow and the developments drawn beside each separate piece, as shown in figure 14-44. Here, only one end and one middle development are drawn. The other two pieces are the same as these.

You must determine the exact points of intersection when two pieces, such as two cylinders or a cylinder and a prism, intersect. This is so you can make developments, for the pieces, that will fit together without gaps or unnecessary overlaps. These intersections are determined by carefully drawing the elements intersecting on orthographic views and then projecting or transferring these intersection points to the developments. The following steps in making developments for a T-joint are shown in figure 14-45.

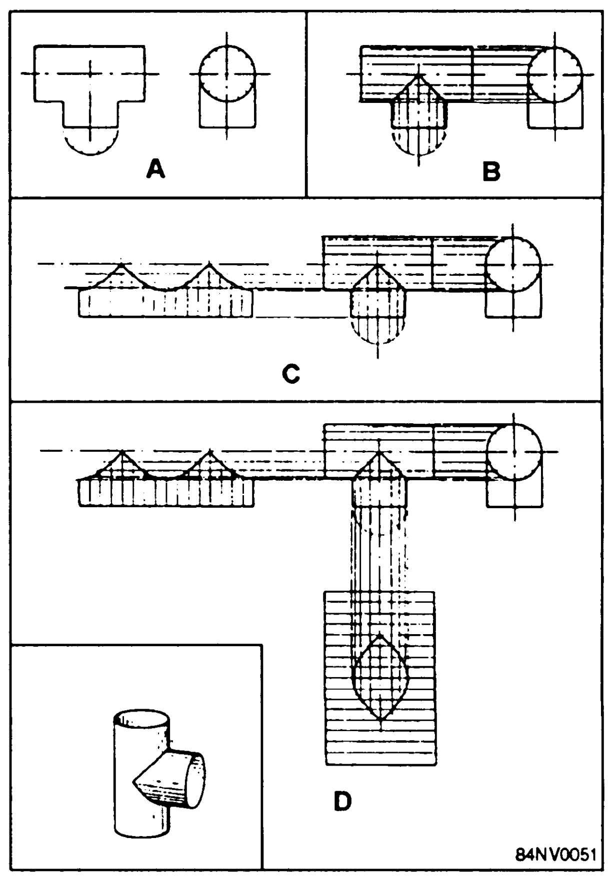


Figure 14-45.—Development of a T-joint with two cylindrical pipes of unequal diameters.

You should refer to this figure as you read the following section. The T-joint consists of two cylinders with equal diameters that intersect at right angles.

1. Draw a front view and a side view of the T-joint. A bottom view representing the open end of the other cylinder might also be drawn. Since this cylinder is perfectly round, a semicircle may be drawn attached to the front view. The division points for the elements can be located on it (view A).
2. Draw equally spaced divisions to locate the elements. Project these divisions to both cylinders. The points where the elements of one cylinder intersect those of the other define the intersection of the two cylinders (view B).
3. Draw the surface of the projecting pipe at one side of the orthographic view so the length of each element can be projected from the front view (view C).
4. Draw the surface of the cross pipe below the front view. Project lines down from the branch pipe to locate the opening for it (view D).

When making the T-joint of two cylindrical pipes of unequal diameter, the procedure differs slightly. Refer to figure 14-46 as you read the following section.

1. Draw the orthographic views.
2. Divide the smaller diameter branch pipe into equal parts. Draw the elements on this pipe in both views (view A). The length of each element is shown in the side view.
3. Project lines from the upper end of each element in the side view to the front view (view B). The intersections of these lines with the vertical lines drawn on the branch pipe define the intersection of the two pipes.
4. Draw the line of intersection on the front view.
5. Draw the surface of the branch pipe to the left, continuing the projection lines to locate the element ends (view C).
6. Draw the surface of the larger diameter main pipe beneath the front view. Project lines down from the branch pipe to locate the opening for it (view D).

Figure 14-47 shows the following steps in drawing a round pipe joint made up of two cylindrical pipes of unequal diameters that intersect at an angle other than 90°.

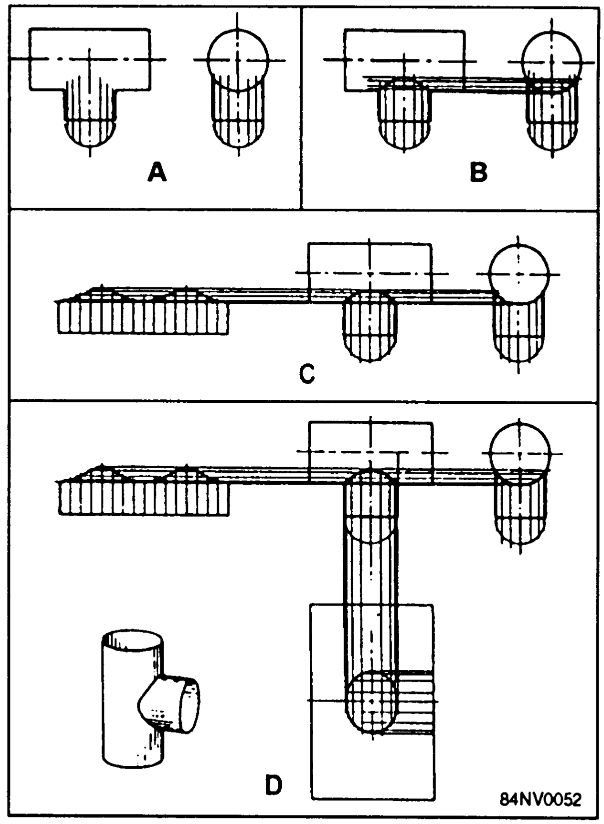


Figure 14-46.—Development of a T-joint with two cylindrical pipes of unequal diameters.

1. Draw the front and top orthographic views (view A). The ellipse formed by the top of the branch pipe may be omitted at this point and drawn later.
2. Draw the elements on the branch pipe in both views (view B).
3. Project lines down from the left end of each element in the top view to the corresponding element in the front view. Draw the line of intersection (view C).
4. Draw the ellipse formed by the end of the branch pipe in the top view. Do this by projecting lines up from the upper end of each element in the front view to the corresponding element in the top view (view D).
5. Draw the pattern of the branch pipe to the right and perpendicular to the pipe the same as in the front view (view E).
6. Draw the pattern for the main pipe to the left, with lines projecting from the intersection of the two pipes on the orthographic view to locate the opening for the branch pipe (view F).

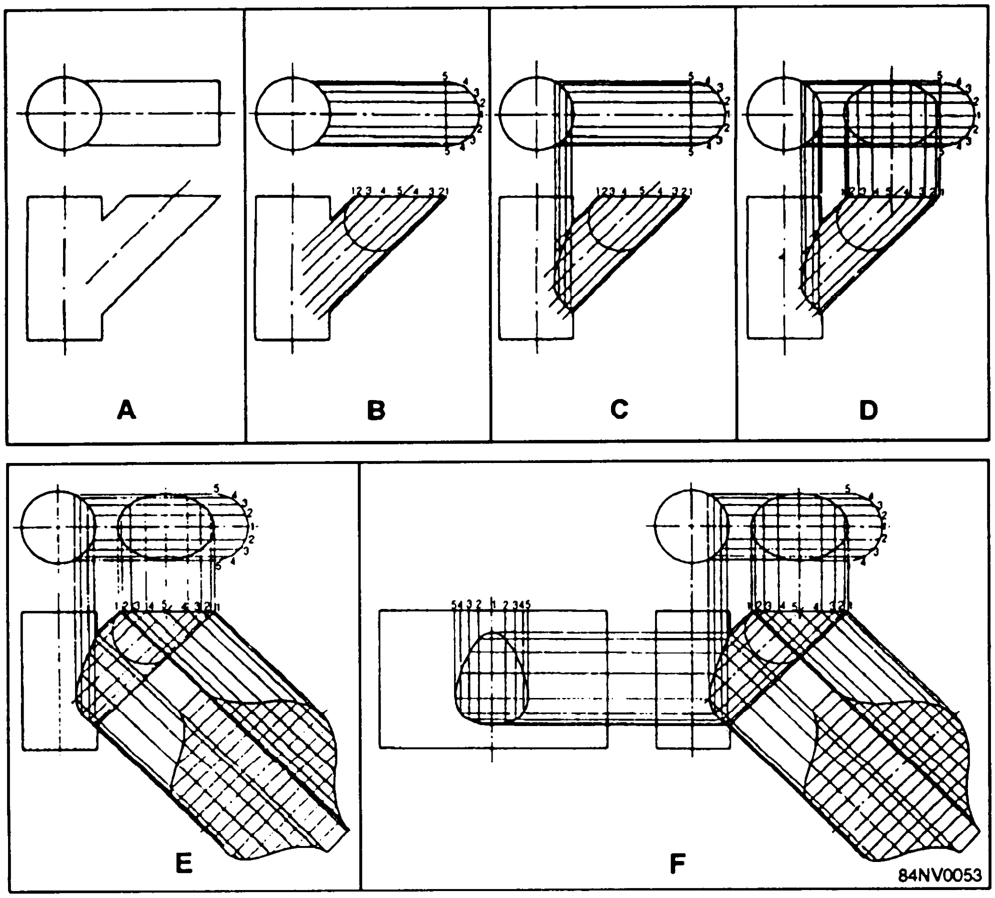


Figure 14-47.—Development of a round pipe joint made of two cylindrical pipes of unequal diameters, intersecting at an angle of other than 90°.

When a pipe joint consists of a rectangular pipe intersecting a round pipe at an angle other than 90°, the procedure is similar. This procedure is shown in figure 14-48 and is described in the following steps:

1. Draw the orthographic views, as shown in view A. Divide the upper surface of the rectangular pipe in the top view by equally spaced elements.
2. Project the points of intersection of these lines with the circle down to the upper and lower surfaces of the branch pipe in the front view (view B).
3. Develop the surface of the rectangular pipe perpendicular to it in the front view (view C).
4. Draw the surface of the round pipe with the opening for the rectangular pipe to the side of the front view (view D).

RADIAL DEVELOPMENT

The sides of a pyramid and the elements of a cone meet at a point called the vertex or apex. These same lines meet at a point in the development of a pyramid or cone and radiate from this point. Therefore, the method of developing pyramids or cones is radial development (fig. 14-49).

Follow the same general procedures in radial development as those used in parallel development. The only major exception is that since the slanting lines of pyramids and cones do not always appear in their true lengths on the orthographic views (fig. 14-49, view A), other procedures must be followed to determine these true lengths.

To find the true lengths of these edges, rotate the pyramid so some of the edges appear in their true lengths (view B). In this case, the lines that appear as horizontal lines in the top view are shown in outline and in their true length in the front view. In other words, when a line appears as horizontal or as a point in the top view, the corresponding line in the front view is its true length. Conversely, when a line appears as horizontal in the front view, the corresponding line in the top view is its true length.

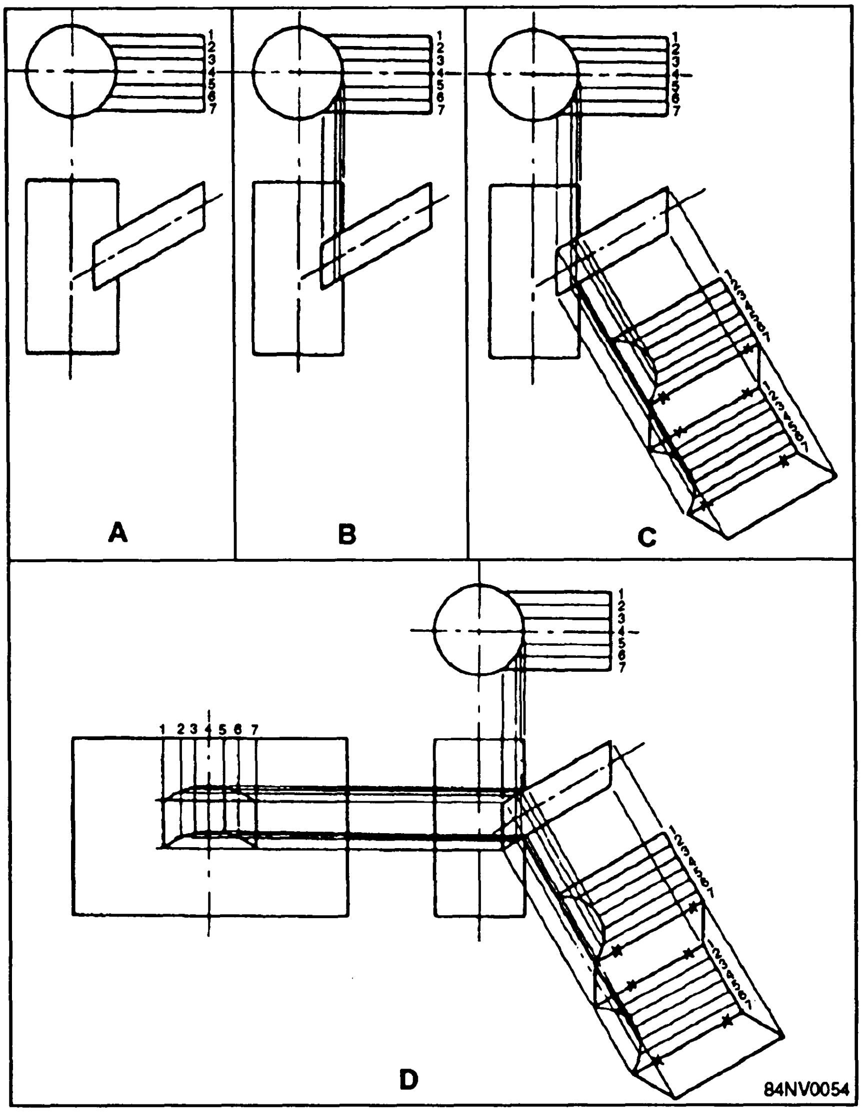


Figure 14-48.—Development of a pipe joint in which a rectangular pipe intersects a round pipe at an angle other than 90°.

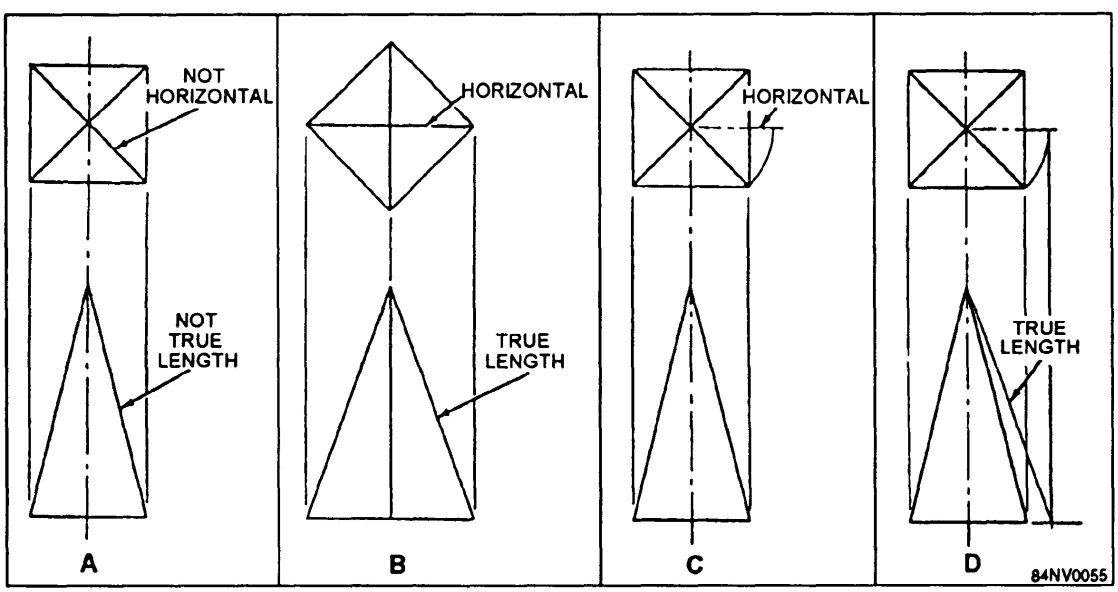


Figure 14-49.—Methods of finding the true length of a line in a radial development.

Instead of rotating the whole pyramid, simply rotate the line of the edge itself into the horizontal on a conventional orthographic view. For example, in view C, the line of an edge from apex to base, as it appears in the top view, is used as the radius for an arc to the horizontal The point of intersection of the arc with the horizontal is projected to the front view. A true-length line for that edge is drawn (view D).

The following steps for developing a truncated pyramid are shown in figure 14-50. This is a transition piece for connecting a large square pipe with a smaller one. Normally, the square ends would end in square collars, which also would be developed.

1. Draw the orthographic views, completing the lines of the sides to the apex (view A).
2. Rotate the line of one edge in the top view to the horizontal and project it to the front view (view W
3. Draw an arc with a radius equal to the length of this true-length line, plus its extension to the apex of the pyramid. Draw a second arc defining the upper limit of the true-length line (view C).
4. Step off lengths along these arcs equal to the sides of the pyramid (view D).
5. Connect these points with the vertex, as shown in view D.

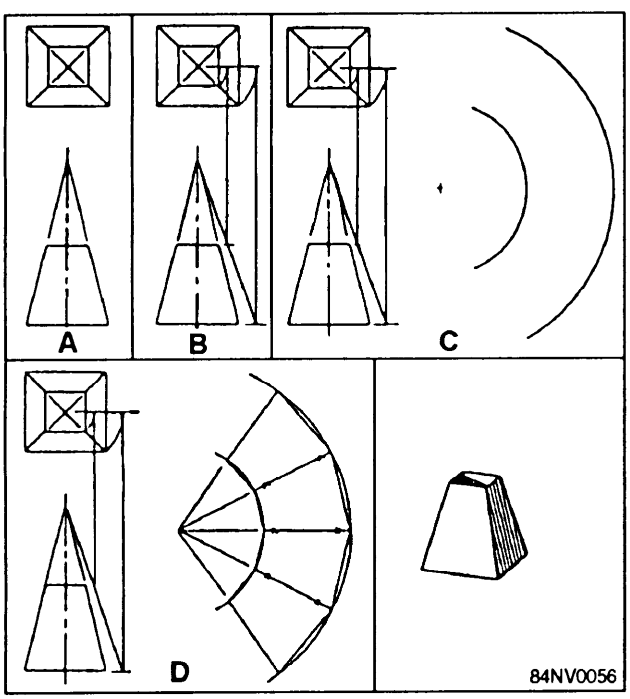


Figure 14-50.—Development of a truncated pyramid.

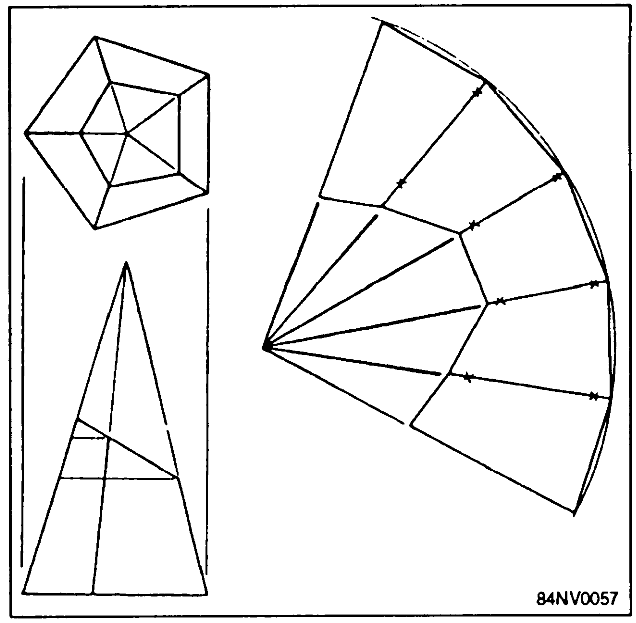


Figure 14-51.—Development of a truncated pentagonal pyramid with the upper corners cut by a slanting plane.

To develop a truncated pentagonal pyramid, like that shown in figure 14-51, follow the same general steps. However, since one lateral edge appears in its true length in the front view, the limits of the other edges can be projected onto the line of this edge to determine the true lengths. Measure the length of each edge. Transfer this measurement to the development.

Figure 14-52 shows the following steps in the development of an offset transition piece. It is offset

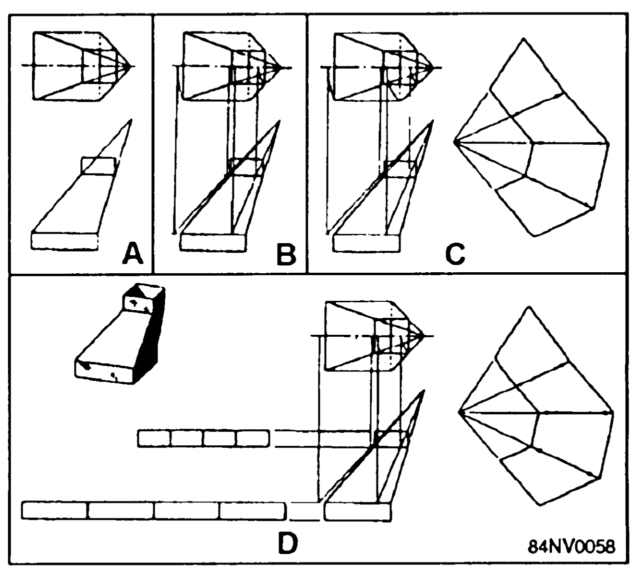


Figure 14-52.—Development of an offset transition piece.

because the center of one end is not in line with the center of the other end. The three parts consist of an upper and a lower section that are truncated rectangular prisms. The third section is a truncated oblique pyramid.

1. Draw the orthographic views, extending the lines of the sides of the pyramid to its apex in both views (view A).
2. Rotate the lines of the sides to the horizontal in the top view. Project the points located on the front view and draw the true-length lines (view W
3. At one side of the views, develop the surface of the oblique square pyramid. Construct one triangle at a time, and take the length of the three sides of each triangle from the views (view C). Draw the upper edges to complete the drawing.
4. Draw the surface patterns of the upper and lower prisms (view D).

The development of a cone is similar to the development of a pyramid. Consider it a pyramid with an infinite number of sides. In actual practice, of course, the number of sides are drawn on the orthographic views and projected to the development. The steps in developing a truncated right cone are shown in figure 14-53.

The truncated right cone has a center line that is perpendicular to its base. The elements on a right cone are all the same length. The true length of these elements is shown by those that fall to the extreme right and left in a front view. These elements are horizontal lines in a top view. A slanting plane cuts the cone in figure 14-53. The end points of the elements between the two outside elements must project to one of the outside lines to determine their true lengths.

To develop a truncated right cone, use the following steps:

1. Draw the orthographic views. Include either a side view (view A) or an auxiliary view of the ellipse formed by the slanting plane. Note that the center of the ellipse must be determined since it does not fall on the center line of the cone. This center point is projected to the side view and defines the length of the minor axis of the ellipse. The length of the major axis is defined by the length of the slanting line in the front view.

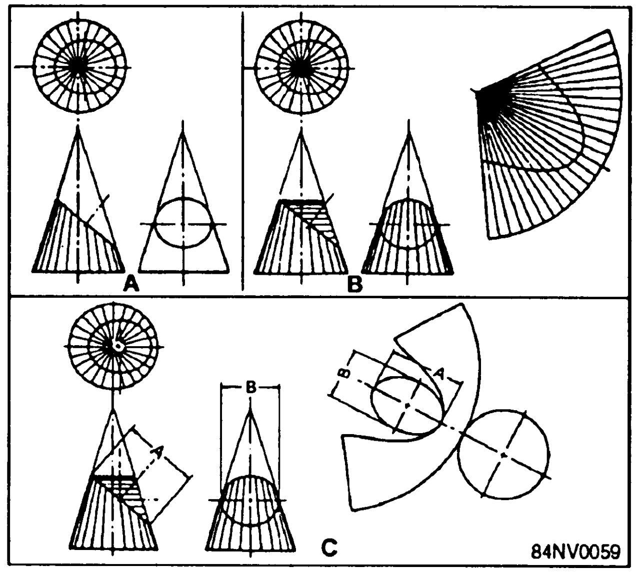


Figure 14-53.—Development of a truncated right cone.

2. Develop the surface pattern of the cone using the length from the apex to the base as a radius for drawing the arc. Step off on this line the equally spaced division of the base. Then, measure each element individually and transfer this measurement to the development. The ends of each of these elements define the curve of the upper edge of the peripheral surface (view B).
3. Draw the base surface circle and the top surface ellipse attached to the peripheral surface (view C).

TRIANGULATION DEVELOPMENT

Triangulation is slower and more difficult than parallel line or radial development, but it is more practical for many types of figures. It is the only method with which the development of warped surfaces may be approximated. In development of triangulation, the piece is divided into a series of triangles, as in radial development. However, there is no one single apex for the triangles. The problem becomes one of finding the true lengths of the varying oblique lines. This is usually done by drawing a true-length diagram.

Figure 14-54 shows the following steps in the triangulation of a warped transition piece joining a large square pipe and a smaller round pipe:

1. Draw the top and front orthographic views (view A).
2. Divide the circle in the top view into several equal spaces and connect the division points with the comers of the square (view B).
3. Transfer the division points to the front view and draw the elements. Some of the triangles curve slightly, but they can be considered flat.
4. Now the true length of each of these elements may be found. Draw a right triangle with a base equal to the length of an element on the top view. Draw it with an altitude equal to the altitude of the corresponding element on the front view. The hypotenuse of the triangle is the true length of the element. In view C, the true-length diagram consists of only three right triangles. Since the piece is symmetrical, several elements are the same length.
5. Draw the surface pattern by constructing one triangle at a time.

Figure 14-55 shows the following steps in developing a rectangular transition piece that is not a true pyramid because the extended lateral edges would not meet at a common vertex. The best way to develop

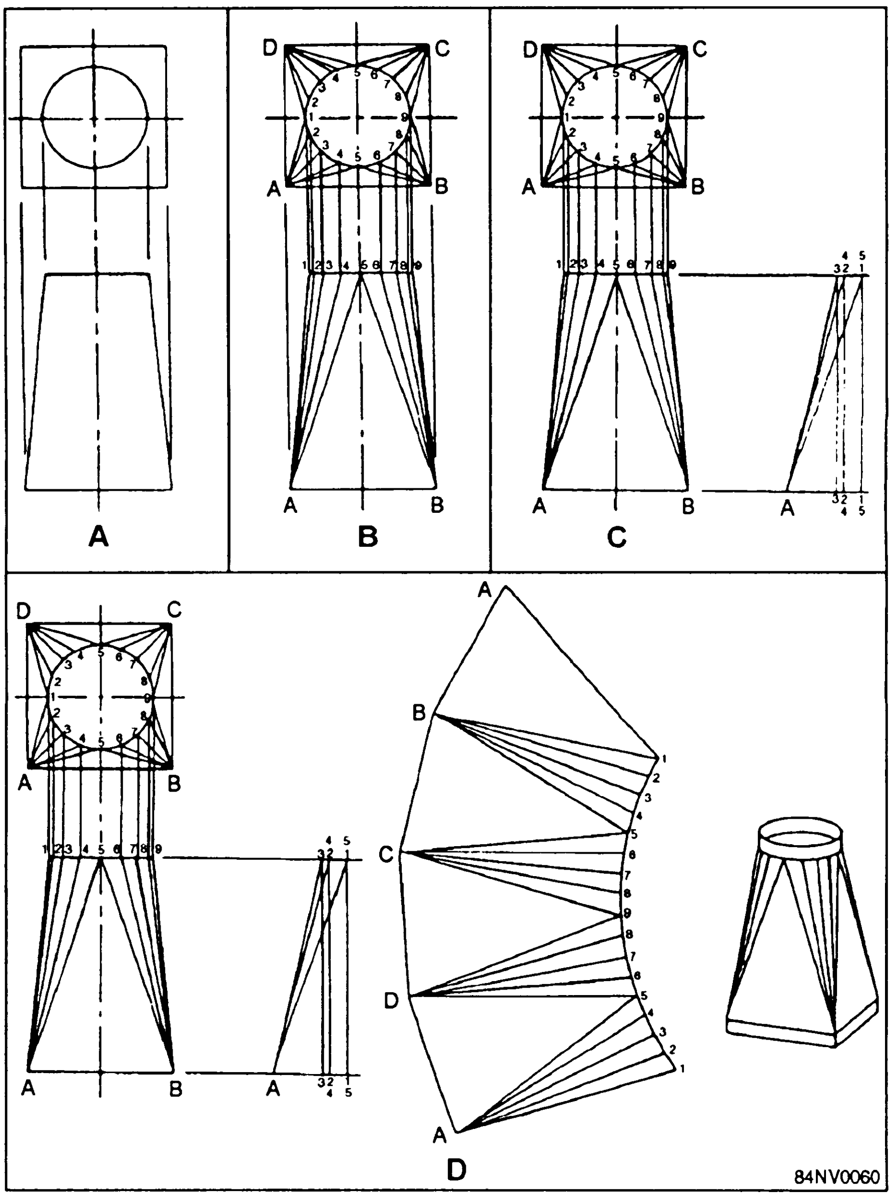


Figure 14-54.—Development by triangulation of a transition piece.

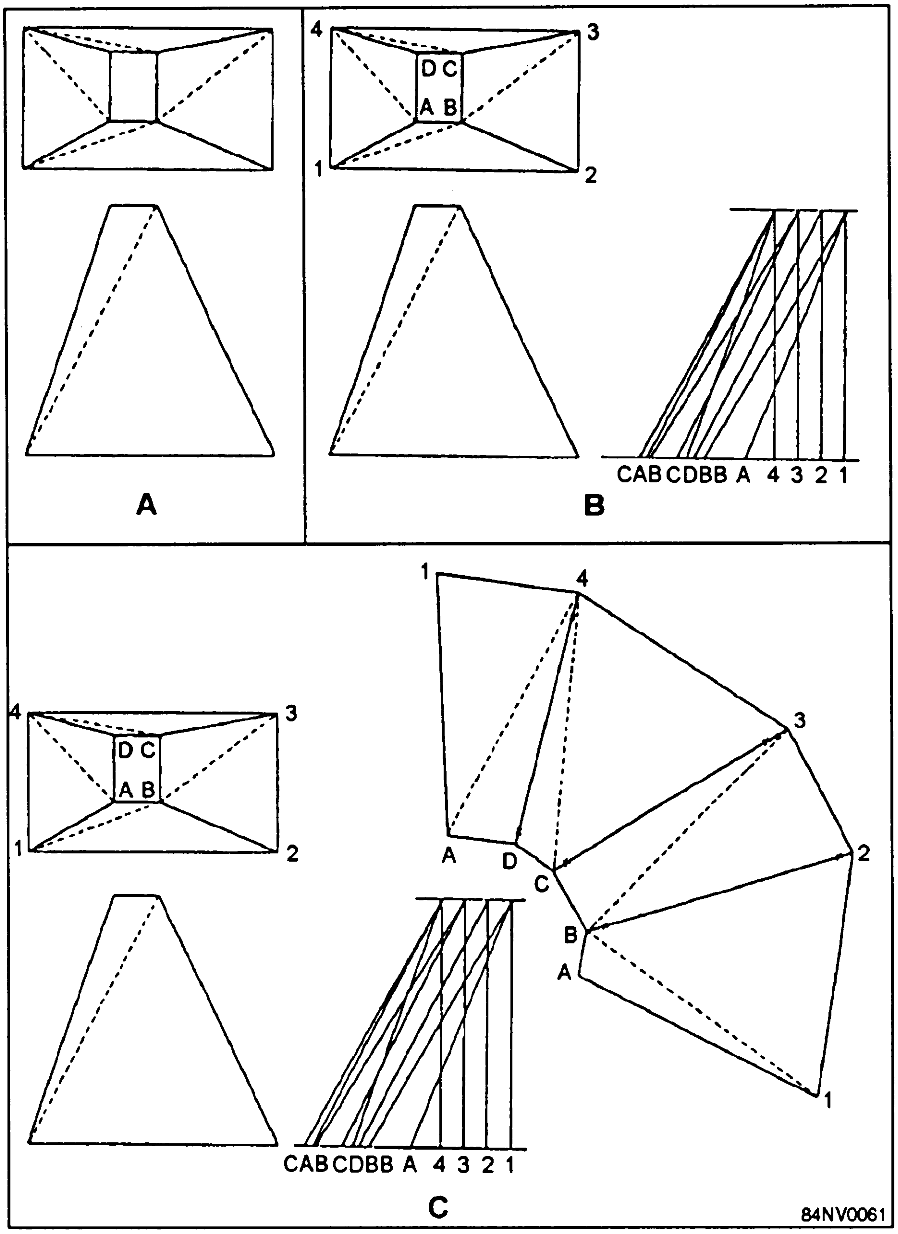


Figure 14-55.—Development of a rectangular transition piece, which is not a true pyramid.

this is by drawing diagonals that split the sides into two triangles. These diagonals are usually drawn as dotted lines to separate them from other elements. Then, the true length of each element is found, and the surface pattern developed by constructing each triangle in turn. To find the true-length lines, draw a true-length diagram.

1. Draw the orthographic views with the bend lines and the diagonals (view A).
2. Draw a true-length diagram of these elements (view B).
3. Draw the surface pattern by constructing one triangle at a time (view C).

The fitting in figure 14-56 has a warped surface. Its base is round and its top is oblong. The following method for development consists of dividing the surface into quadrilaterals of about the same size. A quadrilateral is a plane figure having four sides and four angles. A diagonal is then drawn across each of these to produce two triangles. When the true lengths of these elements have been found, the surface pattern may be drawn triangle by triangle.

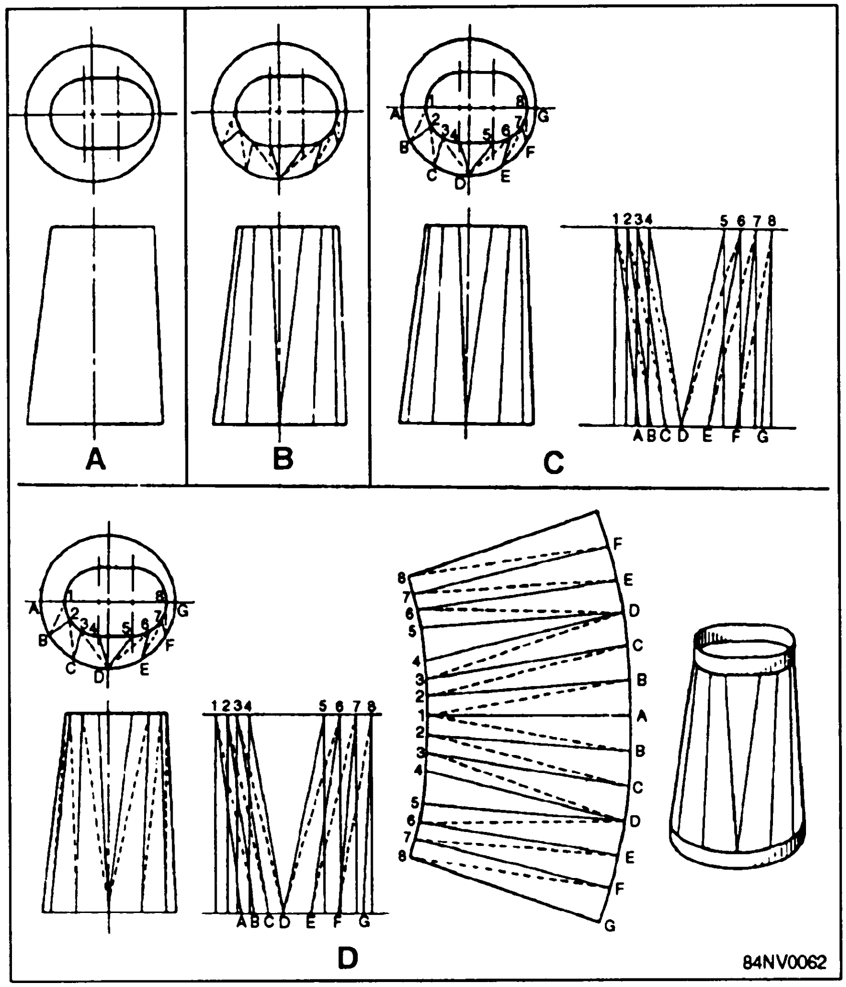


Figure 14-56.—Development of a warped transition piece.

1. Draw the top and front orthographic view (view A).
2. Divide the circle of the base into several equal spaces. Divide the arcs at the ends of the oblong into half as many spaces. Since the transition piece is symmetrical on a central axis, this may be done on only half of the top view. Connect these division points (view B). Use dotted lines for the diagonals to differentiate them.
3. Project the division points to the front view and draw the elements there.
4. Draw the true-length diagram for the elements (view C).
5. Draw an approximation of the surface pattern of the warped surface by constructing one triangle after another (view D).

METRIC SYSTEM

The metric system is an extremely accurate universal system of weights and measures. It is based on a unit called a meter.

NOTE: 1 meter was originally 1/10,000,000 the distance from the earth's equator to its pole. It is a system based on units of ten, making it a very uncomplicated system with which to work. A meter is 39.37 inches long or slightly longer than a yard.

Adding prefixes to the name of the primary unit of measure, such as micrometer or millimeter, form the names of metric denominations

Table 14-1 explains the metric system by showing nomenclature and giving the English measure equivalents.

Tables 14-1, 14-2, 14-3, 14-4, 14-5, and 14-6 are given as a quick reference when solving math-related problems.

Table 14-1.—Metric System and English Conversion

The gram, which is the primary unit of weights, is the weight of one cubic centimeter of pure distilled water at a temperature of 39.2° F., the kilogram is the weight of 1 liter of water; the ton is the weight of 1 cubic meter of water. The gram is used in weighing gold, jewels, and small quantities of things. The kilogram, commonly called kilo for brevity, is used by grocers; the ton is used for weighing heavy articles.

Measures of Pressure

1 pound per square inch	=	144 pounds per square foot 0.068 atmosphere 2.042 inches of mercury at 62° F. 27.7 inches of water at 62° F. 2.31 feet of water at 62° F.
1 atmosphere	=	30 inches of mercury at 62° F. 14.7 pounds per square inch 2116.3 pounds per square foot 33.95 feet of water at 62° F.
1 foot of water at 62° F.	=	62.355 pounds per square foot 0.433 pound per square inch
1 inch of mercury at 62° F.	=	1.132 foot of water 13.58 inches of water 0.491 pound per square inch

Metric and English Conversion Table

Measures of Length

1 millimeter	=	0.03937 inch
1 centimeter	=	0.3937 inch
1 meter	=	39.37 inches 3.2808 feet 1.0936 yards
1 kilometer	=	0.6214 mile
1 inch	=	25.4 millimeters 2.54 centimeters
1 foot	=	304.8 millimeters 0.3048 meter
1 yard	=	0.9144 meter
1 mile	=	1.609 kilometer

Square Measure—Measures of Surface

1 square millimeter	=	0.00155 square inch
1 square centimeter	=	0.155 square inch
1 square meter	=	10.764 square feet 1.196 square yard
1 are	=	0.0247 acre 1076.4 square feet
1 hectare	=	2.471 acres 107,640 square feet
1 square kilometer	=	0.3861 square mile 247.1 acres
1 square inch	=	6.542 square centimeters 654.2 square millimeters
1 square foot	=	0.0929 square meter 9.290 square centimeters
1 square yard	=	0.836 square meter
1 acre	=	0.4047 hectare 40.47 acres
1 square mile	=	2.5899 square kilometers

Cubic Measure—Measures of Volume and Capacity

1 cubic centimeter	=	0.061 cubic inch
1 cubic decimeter	=	61.023 cubic inches 0.0353 cubic foot

Micro, a millionth	=	$\frac{1}{1,000,000}$
Milli, a thousandth	=	$\frac{1}{1000}$
Centi, a hundredth	=	$\frac{1}{100}$
Deci, a tenth	=	$\frac{1}{10}$
Deca, ten	=	10
Hecto, one hundred	=	100
Kilo, one hundred	=	1000
Myria, ten thousand	=	10,000
Mega, one million	=	1,000,000

Principal Units of Metric System

The meter for lengths

The square meter for surfaces

The cubic meter for large volumes

The liter for small volumes

The gram for weights

Measures of Length

10 millimeters (mm.)	= 1 centimeter (cm.)
10 centimeters	= 1 decimeter (dm.)
10 decimeters	= 1 meter (m.)
10 meters	= 1 decameter (Dm.)
10 decameters	= 1 hectometer (Hm.)
10 hectometers	= 1 kilometer (Km.)
10 kilometers	= 1 myriameter

A meter is used in ordinary measurements; the centimeter or millimeter in calculating very small distances; and the kilometer for long distances.

Square Measure—Measures of Surface

100 square millimeters ($mm.^2$)	= 1 square centimeter ($cm.^2$)
100 square centimeters	= 1 square decimeter ($dm.^2$)
100 square decimeters	= 1 square meter ($m.^2$)
100 centiares, or square meters	= 1 are (a.)
100 ares	= 1 hectare (ha.)

The square meter is used for ordinary surfaces; the are, a square, each of whose sides is 10 meters, is the unit of land measure.

Cubic Measure—Measures of Volume

1000 cubic millimeters ($mm.^3$)	= 1 cubic centimeter ($cm.^3$ or cc.)
1000 cubic centimeters	= 1 cubic decimeter ($dm.^3$)
1000 cubic decimeters	= 1 cubic meter ($m.^3$)

The term stere is used to designate the cubic meter in measuring wood and timber. A tenth of a stere is a decistere, and ten steres and a decastere.

Liquid and Dry Measures—Measures of Capacity

10 milliliters (ml.)	= 1 centiliter (cl.)
10 centiliters	= 1 deciliter (dl.)
10 deciliters	= 1 liter (l.)
10 liters	= 1 decaliter (Dl.)
10 decaliters	= 1 hectoliter (Hl.)
10 hectoliters	= 1 kiloliter (Kl.)

The liter, which is a cube each of whose edges is $\frac{1}{10}$ of a meter in length, is the principal unit of measures of capacity. The hectoliter is the unit that is used in measuring large quantities of grain, fruits, roots, and liquids.

Measures of Weight

10 milligrams (mg.)	= 1 centigram (cg.)
10 centigrams	= 1 decigram (dg.)
10 decigrams	= 1 gram (g.)
10 grams	= 1 decagram (Dg.)
10 decagrams	= 1 hectogram (Hg.)
10 hectograms	= 1 kilogram (Kg.)
1000 kilograms	= 1 (metric) ton (T.)

$$1 \text{ cubic meter} = \begin{cases} 35.314 \text{ cubic feet} \\ 1.308 \text{ cubic yards} \\ 264.2 \text{ U.S. gallons} \end{cases}$$

$$1 \text{ liter} = \begin{cases} 1 \text{ cubic decimeter} \\ 61.023 \text{ cubic inches} \\ 0.0353 \text{ cubic foot} \\ 1.0567 \text{ U.S. quarts} \\ 0.2642 \text{ U.S. gallons} \\ 2.202 \text{ lbs. of water at } 62° \text{ F.} \end{cases}$$

1 cubic inch = 16.383 cubic centimeters

1 cubic foot = { 0.02832 cubic meter; 28.317 cubic decimeters; 28.317 liters }

1 cubic yard = 0.7645 cubic meter

1 gallon U.S. = 3.785 liters

1 gallon British = 4.543 liters

Measures of Weight

1 gram = { 0.03216 ounce troy; 0.03527 ounce avoirdupois; 15.432 grains }

1 kilogram = { 2.2046 pounds aviordupois; 35.274 ounces avoirdupois }

1 metric ton = { 0.9843 ton of 2,240 pounds; 19.68 hundredweight; 2204.6 pounds; 1.1023 tons of 2,000 pounds }

1 grain = 0.0648 gram

1 ounce troy = 31.103 grams

1 ounce avoirdupois = 28.35 grams

1 pound = { 0.4536 kilogram; 453.6 grams }

1 ton of 2240 pounds = { 1.016 metric tons; 1016 kilograms }

Inches and Equivalents in Millimeters

Inches	MM	Inches	MM	Inches	MM
1/64	.397	45/64	17.859	26	660.4
1/32	.794	23/32	18.256	27	685.8
3/64	1.191	47/64	18.653	28	711.2
1/16	1.588	3/4	19.050	29	637.6
5/64	1.984	49/64	19.447	30	762.0
3/32	2.381	25/32	19.844	31	787.4
7/64	2.778	51/64	20.241	32	812.8
1/8	3.175	13/16	20.638	33	838.2
9/64	3.572	53/64	21.034	34	863.6
5/32	3.969	27/32	21.431	35	889.0
11/64	4.366	55/64	21.828	36	914.4
3/16	4.763	7/8	22.225	37	939.8
13/64	5.159	57/64	22.622	38	965.2
7/32	5.556	29/32	23.019	39	990.6
15/64	5.953	59/64	23.416	40	1016.0
1/4	6.350	15/16	23.813	41	1041.4
17/64	6.747	61/64	24.209	42	1066.8
9/32	7.144	31/32	24.606	43	1092.2
19/64	7.540	63/64	25.003	44	1117.6
5/16	7.938	1	25.400	45	1143.0
21/64	8.334	2	50.8	46	1168.4
11/32	8.731	3	76.2	47	1193.8
23/64	9.128	4	101.6	48	1219.2
3/8	9.525	5	127.0	49	1244.6
25/64	9.922	6	152.4	50	1270.0
13/32	10.319	7	177.8	51	1295.4
27/64	10.716	8	203.2	52	1320.8
7/16	11.113	9	228.6	53	1346.2
29/64	11.509	10	254.0	54	1371.6
15/32	11.906	11	279.4	55	1397.0
31/64	12.303	12	304.8	56	1422.4
1/2	12.700	13	330.2	57	1447.8
33/64	13.097	14	355.6	58	1473.2
17/32	13.494	15	381.0	59	1498.6
35/64	13.891	16	406.4	60	1524.0
9/16	14.288	17	431.8	61	1549.4
37/64	14.684	18	457.2	62	1574.8
19/32	15.081	19	482.6	63	1600.2
39/64	15.478	20	508.0	64	1625.6
5/8	15.875	21	533.4	65	1651.0
41/64	16.272	22	558.8	66	1676.4
21/32	16.669	23	584.2	67	1701.8
43/64	17.066	24	609.6	68	1727.2
11/16	17.463	25	635.0	69	1752.6

Table 14-1.—Metric System and English Conversion—Continued

Inches and Equivalents in Millimeters—*Continued*

Inches	MM	Inches	MM	Inches	MM
70	1778.0	114	2895.6	158	4013.2
71	1803.4	115	2921.0	159	4038.6
72	1828.8	116	2946.4	160	4064.0
73	1854.2	117	2971.8	161	4089.4
74	1879.6	118	2997.2	162	4114.8
75	1905.0	119	3022.6	163	4140.2
76	1930.4	120	3048.0	164	4165.6
77	1955.8	121	3073.4	165	4191.0
78	1981.2	122	3098.8	166	4216.4
79	2006.6	123	3124.2	167	4241.8
80	2032.0	124	3149.6	168	4267.2
81	2057.4	125	3175.0	169	4292.6
82	2082.8	126	3200.4	170	4318.0
83	2108.2	127	3225.8	171	4343.4
84	2133.6	128	3251.2	172	4368.8
85	2159.0	129	3276.6	173	4394.2
86	2184.4	130	3302.0	174	4419.2
87	2209.8	131	3327.4	175	4445.0
88	2235.2	132	3352.8	176	4470.4
89	2260.6	133	3378.2	177	4495.8
90	2286.0	134	3403.6	178	4521.2
91	2311.4	135	3429.0	179	4546.6
92	2336.8	136	3454.4	180	4572.0
93	2362.2	137	3479.8	181	4597.4
94	2387.6	138	3505.2	182	4622.8
95	2413.0	139	3530.6	183	4648.2
96	2438.4	140	3556.0	184	4673.6
97	2463.8	141	3581.4	185	4699.0
98	2489.2	142	3606.8	186	4724.4
99	2514.6	143	3632.2	187	4749.8
100	2540.0	144	3657.6	188	4775.2
101	2565.4	145	3683.0	189	4800.6
102	2590.8	146	3708.4	190	4826.0
103	2616.2	147	3733.8	191	4851.4
104	2641.6	148	3759.2	192	4876.8
105	2667.0	149	3784.6	193	4902.2
106	2692.4	150	3810.0	194	4927.6
107	2717.8	151	3835.4	195	4953.0
108	2743.2	152	3860.8	196	4978.4
109	2768.6	153	3886.2	197	5003.8
110	2794.0	154	3911.6	198	5029.2
111	2819.4	155	3937.0	199	5054.6
112	2844.8	156	3962.4	200	5080.0
113	2870.2	157	3987.8		

Millimeters and Equivalents in Inches

MM	Inches	MM	Inches	MM	Inches
1/100	.0004	45/100	.0177	89/100	.0350
2/100	.0008	46/100	.0181	90/100	.0354
3/100	.0012	47/100	.0185	91/100	.0358
4/100	.0016	48/100	.0189	92/100	.0362
5/100	.0020	49/100	.0193	93/100	.0366
6/100	.0024	50/100	.0197	94/100	.0370
7/100	.0028	51/100	.0201	95/100	.0374
8/100	.0031	52/100	.0205	96/100	.0378
9/100	.0035	53/100	.0209	97/100	.0382
10/100	.0039	54/100	.0213	98/100	.0386
11/100	.0043	55/100	.0217	99/100	.0390
12/100	.0047	56/100	.0221	1	.0394
13/100	.0051	57/100	.0224	2	.0787
14/100	.0055	58/100	.0228	3	.1181
15/100	.0059	59/100	.0232	4	.1575
16/100	.0063	60/100	.0236	5	.1969
17/100	.0067	61/100	.0240	6	.2362
18/100	.0071	62/100	.0244	7	.2756
19/100	.0075	63/100	.0248	8	.3150
20/100	.0079	64/100	.0252	9	.3543
21/100	.0083	65/100	.0256	10	.3937
22/100	.0087	66/100	.0260	11	.4331
23/100	.0091	67/100	.0264	12	.4724
24/100	.0094	68/100	.0268	13	.5118
25/100	.0098	69/100	.0272	14	.5512
26/100	.0102	70/100	.0276	15	.5906
27/100	.0106	71/100	.0280	16	.6299
28/100	.0110	72/100	.0284	17	.6693
29/100	.0114	73/100	.0287	18	.7087
30/100	.0118	74/100	.0291	19	.7480
31/100	.0122	75/100	.0295	20	.7874
32/100	.0126	76/100	.0299	21	.8268
33/100	.0130	77/100	.0303	22	.8661
34/100	.0134	78/100	.0307	23	.9055
35/100	.0138	79/100	.0311	24	.9449
36/100	.0142	80/100	.0315	25	.9843
37/100	.0146	81/100	.0319	26	1.0236
38/100	.0150	82/100	.0323	27	1.0630
39/100	.0154	83/100	.0327	28	1.1024
40/100	.0158	84/100	.0331	29	1.1417
41/100	.0161	85/100	.0335	30	1.1811
42/100	.0165	86/100	.0339	31	1.2205
43/100	.0169	87/100	.0343	32	1.2598
44/100	.0173	88/100	.0347	33	1.2992

Table 14-1.—Metric System and English Conversion-Continued

Millimeters and Equivalents in Inches—*Continued*

MM	Inches	MM	Inches	MM	Inches
34	1.3386	78	3.0709	122	4.8031
35	1.3780	79	3.1102	123	4.8425
36	1.4173	80	3.1496	124	4.8819
37	1.4567	81	3.1890	125	4.9213
38	1.4961	82	3.2283	126	4.9606
39	1.5354	83	3.2677	127	5.0000
40	1.5748	84	3.3071	128	5.0394
41	1.6142	85	3.3465	129	5.0787
42	1.6535	86	3.3858	130	5.1181
43	1.6929	87	3.4252	131	5.1575
44	1.7323	88	3.4646	132	5.1968
45	1.7717	89	3.5039	133	5.2362
46	1.8110	90	3.5433	134	5.2756
47	1.8504	91	3.5827	135	5.3150
48	1.8898	92	3.6220	136	5.3543
49	1.9291	93	3.6614	137	5.3937
50	1.9685	94	3.7008	138	5.4331
51	2.0079	95	3.7402	139	5.4724
52	2.0472	96	3.7795	140	5.5118
53	2.0866	97	3.8189	141	5.5512
54	2.1260	98	3.8583	142	5.5905
55	2.1654	99	3.8976	143	5.6299
56	2.2047	100	3.9370	144	5.6693
57	2.2441	101	3.9764	145	5.7087
58	2.2835	102	4.0157	146	5.7480
59	2.3228	103	4.0551	147	5.7874
60	2.3622	104	4.0945	148	5.8268
61	2.4016	105	4.1339	149	5.8661
62	2.4409	106	4.1732	150	5.9055
63	2.4803	107	4.2126	151	5.9449
64	2.5197	108	4.2520	152	5.9842
65	2.5591	109	4.2913	153	6.0236
66	2.5984	110	4.3307	154	6.0630
67	2.6378	111	4.3701	155	6.1024
68	2.6772	112	4.4094	156	6.1417
69	2.7165	113	4.4488	157	6.1811
70	2.7559	114	4.4882	158	6.2205
71	2.7953	115	4.5276	159	6.2598
72	2.8346	116	4.5669	160	6.2992
73	2.8740	117	4.6063	161	6.3386
74	2.9134	118	4.6457	162	6.3779
75	2.9528	119	4.6850	163	6.4173
76	2.9921	120	4.7244	164	6.4567
77	3.0315	121	4.7638	165	6.4961

Millimeters and Equivalents in Inches—*Concluded*

MM	Inches	MM	Inches	MM	Inches
166	6.5354	211	8.3071	256	10.079
167	6.5748	212	8.3464	257	10.118
168	6.6142	213	8.3858	258	10.157
169	6.6535	214	8.4252	259	10.197
170	6.6929	215	8.4646	260	10.236
171	6.7323	216	8.5039	261	10.276
172	6.7716	217	8.5433	262	10.315
173	6.8110	218	8.5827	263	10.354
174	6.8504	219	8.6220	264	10.394
175	6.8898	220	8.6614	265	10.433
176	6.9291	221	8.7008	266	10.472
177	6.9685	222	8.7401	267	10.512
178	7.0079	223	8.7795	268	10.551
179	7.0472	224	8.8189	269	10.591
180	7.0866	225	8.8583	270	10.630
181	7.1260	226	8.8976	271	10.669
182	7.1653	227	8.9370	272	10.709
183	7.2047	228	8.9764	273	10.748
184	7.2441	229	9.0157	274	10.787
185	7.2835	230	9.0551	275	10.827
186	7.3228	231	9.0945	276	10.866
187	7.3622	232	9.1338	277	10.905
188	7.4016	233	9.1732	278	10.945
189	7.4409	234	9.2126	279	10.984
190	7.4803	235	9.2520	280	11.024
191	7.5197	236	9.2913	281	11.063
192	7.5590	237	9.3307	282	11.102
193	7.5984	238	9.3701	283	11.142
194	7.6378	239	9.4094	284	11.181
195	7.6772	240	9.4488	285	11.220
196	7.7165	241	9.4882	286	11.260
197	7.7559	242	9.5275	287	11.299
198	7.7953	243	9.5669	288	11.339
199	7.8346	244	9.6063	289	11.378
200	7.8740	245	9.6457	290	11.417
201	7.9134	246	9.6850	291	11.457
202	7.9527	247	9.7244	292	11.496
203	7.9921	248	9.7638	293	11.535
204	8.0315	249	9.8031	294	11.575
205	8.0709	250	9.8425	295	11.614
206	8.1102	251	9.8819	296	11.654
207	8.1496	252	9.9212	297	11.693
208	8.1890	253	9.9606	298	11.732
209	8.2283	254	10.000	299	11.772
210	8.2677	255	10.039		

Table 14-1.—Metric System and English Conversion—Continued

Useful Factors, English Measures

Inches . . . . ×	0.08333	= feet
" . . . . ×	0.02778	= yards
" . . . . ×	0.00001578	= miles
Square inches . . . . ×	0.00695	= square feet
" " . . . . ×	0.0007716	= square yards
Cubic inches . . . . ×	0.00058	= cubic feet
" " . . . . ×	0.0000214	= cubic yards
" " . . . . ×	0.004329	= U.S. gallons
Feet . . . . ×	0.3334	= yards
" . . . . ×	0.00019	= miles
Square feet . . . . . ×	144.0	= square inches
" " . . . . . ×	0.1112	= square yards
Cubic feet . . . . . . ×	1,728	= cubic inches
" " . . . . . . ×	0.03704	= cubic yards
" " . . . . . . ×	7.48	= U.S. gallons
Yards . . . . ×	36	= inches
" . . . . ×	3	= feet
" . . . . ×	0.0005681	= miles
Square yards . . . . ×	1,296	= square inches
" " . . . . . . ×	9	= square feet
Cubic yards . . . . . ×	46,656	= cubic inches
" " . . . . . ×	27	= cubic feet
Miles . . . . ×	63,360	= inches
" . . . . ×	5,280	= feet
" . . . . ×	1,760	= yards
Avoirdupois ounces . ×	0.0625	= pounds
" " . ×	0.00003125	= tons
" pounds . ×	16	= ounces
" " . ×	.001	= hundredweight
" " . ×	.0005	= tons
" " . ×	27.681	= cubic inches of water at 39° F
" tons . . . . ×	32,000	= ounces
" " . . . . ×	2,000	= pounds
Watts . . . . ×	0.00134	= horse power
Horse power . . . . . ×	746	= watts

Weight of round iron per foot = square of diameter in quarter inches + 6.

Weight of flat iron per foot = width × thickness × 10/3.

Weight of flat plates per square foot = 5 pounds for each 1/8 inch thickness.

Useful Factors, Metric Measures

Millimeters × 0.03937	= inches
Millimeters + 25.4	= inches
Centimeters × 0.3937	= inches
Centimeters + 2.54	= inches
Meters × 39.37	= inches
Meters × 3.281	= feet
Meters × 1.094	= yards
Kilometers × 0.621	= miles
Kilometers + 1.6093	= miles
Kilometers × 3280.7	= feet
Square millimeters × 0.0155	= square inches
Square millimeters + 645.1	= square inches
Square centimeters × 0.155	= square inches
Square centimeters + 6.451	= square inches
Square meters × 10.764	= square feet
Square kilometers × 247.1	= acres
Hectares × 2.471	= acres
Cubic centimeters + 16.385	= cubic inches
Cubic centimeters + 3.69	= fluid drachms, U.S. Pharmacopoeia
Cubic centimeters + 29.57	= fluid ounce U.S. Pharmacopoeia
Cubic meters × 35.315	= cubic feet
Cubic meters × 1.038	= cubic yards
Cubic meters × 264.2	= gallons, United States
Liters × 61.022	= cubic inches
Liters × 33.84	= fluid ounces
Liters × 0.2642	= gallons, United States
Liters + 3.78	= gallons, United States
Liters + 28.316	= cubic feet
Hectoliters × 3.531	= cubic feet
Hectoliters × 2.84	= bushels, United States
Hectoliters × 0.131	= cubic yards
Hectoliters × 26.42	= gallons, United States
Grams × 15.432	= grains
Grams (water) + 29.57	= fluid ounces
Grams + 28.35	= ounces, avoirdupois
Kilograms × 2.2046	= pounds
Kilograms × 35.3	= ounces, avoirdupois
Kilograms + 1102.3	= tons, 2000 pounds

Table 14-2.—Mathematics Symbols

SYMBOL	NAME OR MEANING	SYMBOL	NAME OR MEANING
+	Addition or positive value	$\sqrt{\ }$	Square root symbol
−	Subtraction or negative value	$\sqrt[n]{\ }$	Radical symbol. Letter n represents a number indicating which root is to be taken.
±	Positive or negative value		
·	Multiplication dot (Centered; not to be mistaken for decimal point.)	i or j	Imaginary unit; operator j for electronics; represents $\sqrt{-1}$.
×	Multiplication symbol	∞	Infinity symbol
( )	Parentheses	...	Ellipses. Used in series of numbers in which successive numbers are predictable by their conformance to a pattern; meaning is approximated by "etc."
[ ]	Brackets } Grouping symbols		
{ }	Braces		
%	Percent		
+	Division symbol	$\log_a N$	Logarithm of N to the base a.
:	Ratio symbol	log N	Logarithm of N to the base 10. (understood)
: :	Proportion symbol	ln N	Natural or Napierian logarithm of N. Base of the natural or Napierian logarithm system.
=	Equality symbol		
≠	"Not equal" symbol	$\lvert X \rvert$	Absolute value of X.
<	Less than	π	Pi. The ratio of the circumference of any circle to its diameter. Approximate numerical value is 22/7.
≤	Less than or equal to		
>	Greater than		
≥	Greater than or equal to		Therefore
∝	"Varies directly as" or "is proportional to" (Not to be mistaken for Greek alpha (α).)	∠ or ∡	Angle

Table 14-3.—Table of Decimal Equivalents of Fractions of an Inch

1/64------ 0.0156	17/64 ---- 0.2656	33/64 ---- 0.5156	49/64 ---- 0.7656
1/32------ .0313	9/32------ .2813	17/32 ---- .5313	25/32 ---- .7813
3/64------ .0469	19/64 ---- .2969	35/64 ---- .5469	51/64 ---- .7969
1/16------ .0625	5/16------ .3125	9/16------ .5625	13/16 ---- .8125
5/64------ .0781	21/64 ---- .3281	37/64 ---- .5781	53/64 ---- .8281
3/32------ .0938	11/32 ---- .3438	19/32 ---- .5938	27/32 ---- .8438
7/64------ .1094	23/64 ---- .3594	39/64 ---- .6094	55/64 ---- .8594
1/8 ------ .125	3/8 ------ .375	5/8 ------ .625	7/8 ------ .875
9/64------ .1406	25/64 ---- .3906	41/64 ---- .6406	57/64 ---- .8906
5/32------ .1563	13/32 ---- .4063	21/32 ---- .6563	29/32 ---- .9063
11/64 ---- .1719	27/64 ---- .4219	43/64 ---- .6719	59/64 ---- .9219
3/16------ .1875	7/16------ .4375	11/16 ---- .6875	15/16 ---- .9375
13/64 ---- .2031	29/64 ---- .4531	45/64 ---- .7031	61/64 ---- .9531
7/32------ .2188	15/32 ---- .4688	23/32 ---- .7188	31/32 ---- .9688
15/64 ---- .2344	31/64 ---- .4844	47/64 ---- .7344	63/64 ---- .9844
1/4 ------ .25	1/2 ------ .5	3/4 ------ .75	1 ------- 1.0

Table 14-4.—Weights and Measures

Distance

12 inches = 1 foot (ft)

3 feet = 1 yard (yd)

5-1/2 yards = 1 rod (rd)

16-1/2 feet = 1 rod

1,760 yards = 1 statute mile (mi)

5,280 feet = 1 statute mile

Additional measures of length occasionally used

1000 mils = 1 inch; 3 inches = 1 palm; 4 inches = 1 hand

9 inches = 1 span; 2-1/2 feet = 1 military space

5-1/2 yards or 16-1/2 feet = 1 rod; 2 yards = 1 fathom; a cable length = 120 fathoms = 720 feet;

1 inch = 0.0001157 cable length = 0.013889 fathom = 0.111111 span.

Old Land or Surveyors' Measure*

7.92 inches = 1 link (l.)

100 links, or 66 feet, or 4 rods = 1 chain (ch.)

10 chains or 220 yards = 1 furlong

8 furlongs or 80 chains = 1 mile (mi.)

*Sometimes called Gunter's Chain.

Nautical Measure

6080.26 feet or 1.15156 statute miles = 1 nautical mile or knot†

3 nautical miles = 1 league

60 nautical miles, or 69.169 statute miles = 1 degree at the equator

360 degrees = circumference of the earth at the equator

†The value varies according to different measures of the earth's diameter.

Square Measures–Measures of Surface

144 square inches (sq. in.) = 1 square foot (sq. ft.)

9 square feet = 1 square yard (sq. yd.)

$30\frac{1}{4}$ square yards or $272\frac{1}{4}$ square feet = 1 square rod (sq. rd.)

160 square rods or 43,560 square feet	= 1 acre (A.)
640 acres	= 1 square mile (sq. mi.)

Surveyors' Measure

16 square rods	= 1 square chain (sq. ch.)
10 square chains	= 1 acre (A.)
640 acres	= 1 square mile (sq. mi.)
1 square mile	= 1 section (sec.)
36 sections	= 1 township (tp.)

Solid or Cubic Measure–Measures of Volume

1728 cubic inches (cu. in.) = 1 cubic foot (cu. ft.)

27 cubic feet = 1 cubic yard (cu. yd.)

The following measures are also used for wood and masonry.

1 cord of wood = a pile, 4 × 4 × 8 feet = 128 cubic feet

1 perch of masonry = $16\frac{1}{2} \times 1\frac{1}{2} \times 1$ foot = $24\frac{3}{4}$ cubic feet

Shipping Measure

Register Ton—For register tonnage or for measuring entire internal capacity of a ship or vessel:

100 cubic feet = 1 register ton

Shipping Ton—For the mreasurement of cargo.

40 cubic feet = 1 United States shipping ton = 32.143 U.S. bushels

42 cubic feet = 1 British shipping ton = 32.719 imperial bushels.

Carpenter's Rule—To find the weight a vessel will carry, multiply the length of keel by the breadth at main beam by the depth of the hold in feet and divide by 95 (the cubic feet allowed for a ton). The result will be the tonnage.

Dry Measure

2 cups = 1 pint (pt)

2 pints = 1 quart (qt)

4 quarts = 1 gallon (gal)

8 quarts = 1 peck (pk)

4 pecks = 1 bushel (bu)

Counting Units

12 units	= 1 dozen (doz)
12 dozen	= 1 gross
144 units	= 1 gross
24 sheets	= 1 quire
480 sheets	= 1 ream

Equivalents

1 cubic foot of water weighs 62.5 pounds (approx) = 1,000 ounces

1 gallon of water weighs 8-1/3 pounds (approx)

1 cubic foot = 7.48 gallons

1 inch = 2.54 centimeters

1 foot = 30.4801 centimeters

1 meter = 39.37 inches

1 liter = 1.05668 quarts (liquid) = 0.90808 quart (dry)

1 nautical mile = 6,080 feet (approx)

1 fathom = 6 feet

1 shot of chain = 15 fathoms

Liquid Measure

3 teaspoons (tsp) = 1 tablespoon (tbsp)

16 tablespoons = 1 cup

2 cups = 1 pint

16 fluid ounces (oz) = 1 pint

4 gills (gi.) = 1 pint (pt.)

2 pints = 1 quart (qt.)

4 quarts = 1 gallon (gal.) U.S. 231 cubic inches; British 277.274 cubic inches

1 cubic foot = 7.48 U.S. gallons

Table 14-4.—Weights and Measures—Continued

Old Liquid Measure

$31\frac{1}{2}$ gallons	= 1 barrel (bbl.)
42 gallons	= 1 tierce
2 barrels or 63 gallons	= 1 hogshead (hhd.)
84 gallons or 2 tierces	= 1 puncheon
2 hogsheads or 4 barrels or 126 gallons	= 1 pipe or butt
2 pipes or 3 puncheons	= 1 tun

Apothecaries' Fluid Measure

60 minims = 1 fluid drachm; 8 drachms = 1 fluid ounce

1 U.S. fluid ounce = 8 drachms = 1.805 cubic inch = $\frac{1}{128}$ U.S. gallon. The fluid ounce in Great Britain is 1.732 cubic inches.

Measures of Weight

Avoirdupois or Commercial Weight

16 drachms or 437.5 grains	= 1 ounce (oz.)
16 ounces or 7000 grains	= 1 pound (lb.)
2000 pounds	= 1 net or short ton
2240 pounds	= 1 gross or long ton
2204.6 pounds	= 1 metric ton

Measures of weight occasionally used in collecting duties on foreign goods at U.S. custom houses and in freighting coal are:

1 hundredweight = 4 quarters = 112 pounds (1 gross or long ton = 20 hundredweight); 1 quarter = 28 pounds; 1 stone = 14 pounds; 1 quintal = 100 pounds.

Troy Weight*

24 grains	= 1 pennyweight (pwt.)
20 pennyweights	= 1 ounce (oz.)
12 ounces or 5760 grains	= 1 pound (lb.)

A carat of the jewelers, for precious stones = 3.2 grains in the United States. The International carat = 3.168 grains or 200 milligrams. In avoirdupois, apothecaries' and troy weights, the grain is the same, 1 pound troy = 0.82286 pound avoirdupois.

*Used for weighing gold, silver, jewels, etc.

Apothecaries' Weight†

20 grains (gr.)	= 1 scruple (℈)
3 scruples	= 1 drachm (ʒ)
8 drachms	= 1 ounce (℥)
12 ounces	= 1 pound troy (lb.)

†This table is used in compounding medicines and prescriptions.

Measures of Time

one millionth of a second	= 1 microsecond (µsec.)
one thousandth of a second	= 1 millisecond (msec.)
1/3600 hour	= 1 second (sec.)
60 seconds (sec.)	= 1 minute (min.)
60 minutes	= 1 hour (hr.)
24 hours	= 1 day (da.)
7 days	= 1 week (wk.)
365 days	= 1 solar year (yr.)
366 days	= 1 leap-year (every four years)
100 years	= 1 century

By the Gregorian calendar every year in which the number is divisible by 4 is a leap year except that the centesimal years (each 100 years: 1800, 1900, 2000, etc.) are leap-years only when the number of the year is divisible by 400.

Water Conversion Factors

U.S. gallons	×	8.33	=	pounds
U.S. gallons	×	0.13368	=	cubic feet
U.S. gallons	×	231	=	cubic inches
U.S. gallons	×	0.83	=	English gallo
U.S. gallons	×	3.78	=	liters
English gallons (Imperial)	×	10	=	pounds
English gallons (Imperial)	×	0.16	=	cubic feet
English gallons (Imperial)	×	277.274	=	cubic inches
English gallons (Imperial)	×	1.2	=	U.S. gallons
English gallons (Imperial)	×	4.537	=	liters
Cubic inches of water (39.1°)	×	0.036024	=	pounds
Cubic inches of water (39.1°)	×	0.004329	=	U.S. gallons
Cubic inches of water (39.1°)	×	0.003607	=	English gallo
Cubic inches of water (39.1°)	×	0.576348	=	ounces
Cubic feet (of water) (39.1°)	×	62.425	=	pounds
Cubic feet (of water) (39.1°)	×	7.48	=	U.S. gallons
Cubic feet (of water) (39.1°)	×	6.232	=	English gallo
Cubic feet (of water) (39.1°)	×	0.028	=	tons
Pounds of water	×	27.72	=	cubic inches
Pounds of water	×	0.01602	=	cubic feet
Pounds of water	×	0.12	=	U.S. gallons
Pounds of water	×	0.10	=	English gallo

Table 14-4.—Weights and Measures—Continued

Miscellaneous Tables

Numbers		Circular and Angular Measures	
12 units	= 1 dozen	60 seconds (″)	= 1 minute (′)
12 dozen	= 1 gross	60 minutes	= 1 degree (°)
12 gross	= 1 great gross	90 degrees	= 1 quadrant
20 units	= 1 score	360 degrees	= 1 circumference

Table 14-5.—Rectangular Capacities

RECTANGULAR TANKS
Capacity in U.S. Gallons Per Foot of Depth

Widths, Feet	Length of Tank—in Feet						
	2	2 1/2	3	3 1/2	4	4 1/2	5
2	29.92	37.40	44.88	52.36	59.84	67.32	74.81
2 1/2	—	46.75	56.10	65.45	74.81	84.16	93.51
3	—	—	67.32	78.55	89.77	101.0	112.2
3 1/2	—	—	—	91.64	104.7	117.8	130.9
4	—	—	—	—	119.7	134.6	149.6
4 1/2	—	—	—	—	—	151.5	168.3
5	—	—	—	—	—	—	187.0
	5 1/2	6	6 1/2	7	7 1/2	8	8 1/2
2	82.29	89.77	97.25	104.7	112.2	119.7	127.2
2 1/2	102.9	112.2	121.6	130.9	140.3	149.6	159.0
3	123.4	134.6	145.9	157.1	168.3	179.5	190.8
3 1/2	144.0	157.1	170.2	183.3	196.4	209.5	222.5
4	164.6	179.5	194.5	209.5	224.4	239.4	254.3
4 1/2	185.1	202.0	218.8	235.6	252.5	269.3	286.1
5	205.7	224.4	243.1	261.8	280.5	299.2	317.9
5 1/2	226.3	246.9	267.4	288.0	308.6	329.1	349.7
6	—	269.3	291.7	314.2	336.6	359.1	381.5
6 1/2	—	—	316.1	340.2	364.7	389.0	413.3
7	—	—	—	366.5	392.7	418.9	445.1
7 1/2	—	—	—	—	420.8	448.8	476.9
8	—	—	—	—	—	478.8	508.7
8 1/2	—	—	—	—	—	—	540.5
	9	9 1/2	10	10 1/2	11	11 1/2	12
2	134.6	142.1	149.6	157.1	164.6	172.1	179.5
2 1/2	168.3	177.7	187.0	196.4	205.7	215.1	224.4
3	202.0	213.2	224.4	235.6	246.9	258.1	269.3
3 1/2	235.6	248.7	261.8	274.9	288.0	301.1	314.2
4	269.3	284.3	299.2	314.2	329.1	344.1	359.1
4 1/2	303.0	319.3	336.6	353.5	370.3	387.1	403.9
5	336.6	355.3	374.0	392.7	411.4	430.1	448.8
5 1/2	370.3	390.9	411.4	432.0	452.6	473.1	493.7
6	403.9	426.4	448.8	471.3	493.7	516.2	538.6
6 1/2	437.6	461.9	486.2	510.5	534.9	559.2	583.5
7	471.3	497.5	523.6	549.8	576.0	602.2	628.4
7 1/2	504.9	533.0	561.0	589.1	617.1	645.2	673.2
8	538.6	568.5	598.4	628.4	658.3	688.2	718.1
8 1/2	572.3	604.1	635.8	667.6	699.4	731.2	763.0
9	605.9	639.6	673.2	706.9	740.6	774.2	807.9
9 1/2	—	675.1	710.6	746.2	781.7	817.2	852.3
10	—	—	748.1	785.5	822.9	860.3	897.7
10 1/2	—	—	—	824.7	864.0	903.3	942.5
11	—	—	—	—	905.1	946.3	987.4
11 1/2	—	—	—	—	—	989.3	1032
12	—	—	—	—	—	—	1077

U.S. Gallon of water weighs 8.34523 pounds avoirdupois at 4° C.

Table 14-6.—Circular Capacities

Diam., Ft.	In	Gallons	Diam., Ft.	In	Gallons	Diam., Ft.	In	Gallons
1		5.875	3	6	71.97	5	11	205.7
1	1	6.895	3	7	75.44	6		211.5
1	2	7.997	3	8	78.99	6	3	229.5
1	3	9.180	3	9	82.62	6	6	248.2
1	4	10.44	3	10	86.33	6	9	267.7
1	5	11.79	3	11	90.13	7		287.9
1	6	13.22	4		94.00	7	3	308.8
1	7	14.73	4	1	97.96	7	6	330.5
1	8	16.32	4	2	102.0	7	9	352.0
1	9	17.99	4	3	106.1	8		376.0
1	10	19.75	4	4	110.3	8	3	399.9
1	11	21.58	4	5	114.6	8	6	424.5
2		23.50	4	6	119.0	8	9	449.8
2	1	25.50	4	7	123.4	9		475.9
2	2	27.58	4	8	127.9	9	3	502.7
2	3	29.74	4	9	132.6	9	6	530.2
2	4	31.99	4	10	137.3	9	9	558.5
2	5	34.31	4	11	142.0	10		587.5
2	6	36.72	5		146.9	10	3	617.3
2	7	39.21	5	1	151.8	10	6	647.7
2	8	41.78	5	2	156.8	10	9	679.0
2	9	44.43	5	3	161.9	11		710.9
2	10	47.16	5	4	167.1	11	3	743.6
3	11	49.98	5	5	172.4	11	6	777.0
3		52.88	5	6	177.7	11	9	811.1
3	1	55.86	5	7	183.2	12		846.0
3	2	58.92	5	8	188.7	12	3	881.6
3	3	62.06	5	9	194.2	12	6	918.0
3	4	65.28	5	10	199.9	12	9	955.1
3	5	68.58						

U.S. Gallon of water weighs 8.34523 Pounds Avoirdupois at 4° C.

SUMMARY

In this chapter, you have been working problems that you will meet in your job. This chapter only presents the math basics. If you should need further help, see the references listed at the beginning of this chapter.

CHAPTER 15

PIPING SYSTEMS

LEARNING OBJECTIVES

Upon completion of this chapter, you will be able to do the following:

- *Describe the two methods of manufacturing piping and tubing, and discuss the different types and sizes of each.*
- *Identify some of the fittings used for shipboard pipefitting operations, and describe the proper removal and installation procedures to follow.*
- *Identify the various valves used in piping systems.*
- *Describe the type, class, pressures, and number marking system of standard pipefittings and piping materials used on board U.S. naval ships.*
- *Describe the design, types, and sizes of piping systems, and the characteristics of liquids, gases, and vapors carried by shipboard piping systems.*
- *Identify, the hazards and safety precautions involved with piping systems.*
- *Describe the various materials used in insulation and lagging of piping systems, and explain the hazards and safety requirements involved.*

INTRODUCTION

As a Hull Maintenance Technician, you will repair or modify piping systems, and you may also install new systems. To do this, you will need to know the materials you should use. These include pipes, tubes, valves, traps, drains, strainers, connection fittings, expansion joints, packing, and gaskets. The type of system you are working on will determine whether you use iron, steel, copper, plastic, or alloy materials.

In this chapter, we will discuss pipefitting materials and the different types of piping systems.

PIPING AND TUBING

The Naval Sea Systems Command defines piping as an assembly that is composed of pipe or tubing, valves, fittings, and related components that form either a whole or part of a system that is to be used to transfer fluids (liquids and gases).

It is a little harder to define pipe and tubing. In commercial usage, there is no clear distinction between pipe and tubing. The correct designation for each tubular product is established by the manufacturer. If the manufacturer calls a product pipe, it is pipe. If the manufacturer calls it tubing, it is tubing.

In the Navy, however, a distinction is made between pipe and tubing. This distinction is based on the manner in which the sizes of the tubular products are identified.

There are three important dimensions of any tubular product: outside diameter (OD), inside diameter (ID), and wall thickness. A tubular product is called TUBING if its size is identified by actual measured OD and by actual measured wall thickness. A tubular product is called PIPE if its size is identified by a nominal dimension called iron pipe size (IPS) and by reference to a schedule designation for its wall thickness.

The size identification of tubing is simple because it consists of actual measured dimensions. However, the terms used for identifying pipe sizes will require some explanation. A nominal dimension such as IPS is close, but not necessarily identical, to the actual measured dimension. For example, a pipe with a nominal pipe size of 3 inches has an actual measured OD of 3.50 inches. A pipe with a nominal pipe size (NPS) of 2 inches has an actual measured OD of 2.375 inches. For pipe that is 12 inches or larger, the NPS and the actual measured OD are the same. For example, a pipe with an NPS of 14 inches has an actual measured OD of 14 inches. Nominal dimensions are used to simplify the standardization of pipe fittings and pipe taps and threading dies.

The wall thickness of pipe is identified by reference to wall thickness schedules established by the American Standards Association. As an example, table 15-1 shows four schedules: 40, 80, 120, and 160. Each of these schedules shows a different wall thickness and, therefore, a different ID for any given NPS.

Assume that you have a pipe with a nominal size of 4 inches. Using table 15-1, you can see that a 4-inch pipe can have the following ID and OD dimensions.

Schedule	DIA	OD	ID	Wall
40	4	4.500	4.026	0.237
80	4	4.500	3.826	0.337
120	4	4.500	3.624	0.438
160	4	4.500	3.438	0.531

Therefore, you can use a pipe schedule to select either a greater or smaller pipe thickness depending on the requirements of the job.

You may have seen pipe identified as STANDARD (Std), EXTRA STRONG (XS), and DOUBLE EXTRA STRONG (XXS). These designations also refer to wall thickness. Figure 15-1 shows the relative wall thickness of pipes having the same NPS (OD). Note that the ID is reduced as the wall thickness is increased. Pipe is manufactured in a number of different wall

Table 15-1.—Schedule Designations of Pipe Size

SCHEDULE 40				SCHEDULE 80			SCHEDULE 120			
DIA.	O.D.	I.D.	WALL	O.D.	I.D.	WALL	DIA.	O.D.	I.D.	WALL
1/8	0.405	0.269	0.068	0.405	0.215	0.095	4	4.500	3.624	0.438
1/4	0.540	0.364	0.088	0.540	0.302	0.119	5	5.563	4.653	0.500
3/8	0.675	0.493	0.091	0.675	0.423	0.126	6	6.625	5.501	0.562
1/2	0.840	0.622	0.109	0.840	0.546	0.147	8	8.625	7.189	0.718
3/4	1.050	0.824	0.113	1.050	0.742	0.154				
1	1.315	1.049	0.133	1.315	0.957	0.179	SCHEDULE 160			
1-1/4	1.660	1.380	0.140	1.660	1.278	0.191	1/2	0.840	0.466	0.187
1-1/2	1.900	1.610	0.145	1.900	1.500	0.200	3/4	1.050	0.614	0.218
2	2.375	2.067	0.154	2.375	1.939	0.218	1	1.315	0.815	0.250
2-1/2	2.875	2.469	0.203	2.875	2.323	0.276	1-1/4	1.660	1.160	0.250
3	3.500	3.068	0.216	3.500	2.900	0.300	1-1/2	1.900	1.338	0.281
3-1/2	4.000	3.548	0.226	4.000	3.364	0.318	2	2.375	1.689	0.343
4	4.500	4.026	0.237	4.500	3.826	0.337	2-1/2	2.875	2.125	0.375
4-1/2	5.000	4.506	0.247	5.000	4.290	0.355	3	3.500	2.624	0.438
5	5.563	5.047	0.258	5.563	4.813	0.375	4	4.500	3.438	0.531
6	6.625	6.065	0.280	6.625	5.761	0.432	5	5.563	4.313	0.625
8	8.625	7.981	0.322	8.625	7.625	0.500	6	6.625	5.189	0.718
							8	8.625	6.813	0.906

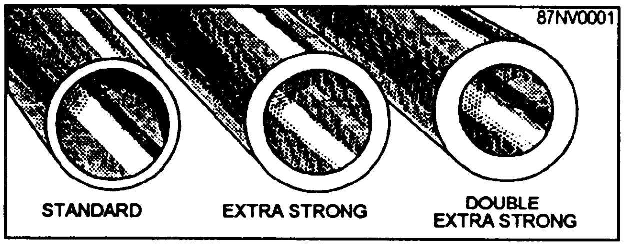


Figure 15-1.—Wall thickness designations.

thicknesses. You will find that some pipe will not fit into the standard, extra strong, and double extra strong classifications. Therefore, the wall thickness schedules are being used increasingly more because they identify more wall thicknesses than can be identified under the strong, extra strong, and double extra strong classifications.

The standard means of identifying the size and wall thickness of pipe and tubing have been briefly described here. However, you will sometimes see pipe and tubing identified by another means. For example, you may see some tubing identified by ID rather than by OD. And, you may see some pipe identified by NPS, by OD, by ID, by actual wall thickness, or by a combination of these measurements.

METHODS OF MANUFACTURE

There are two main processes used to manufacture pipes and other tubular products: the welding process and the seamless process. The welding processes are used primarily to manufacture iron and steel tubular products. The seamless processes are used to manufacture both ferrous and nonferrous tubular products.

Welding Processes

The welding processes used for the production of pipe and other tubular products are usually classified as butt-weld, lapweld, and electric-weld processes.

The butt-weld process is used in the manufacture of ferrous pipe up to about 4 inches in diameter. The edges of the material are usually squared off, as shown in figure 15-2, but they may be slightly beveled. The material is heated to welding temperature and drawn through a die that forms the material into a cylindrical shape and welds the seam.

The lap-weld process is used in the manufacture of ferrous pipe up to about 30 inches in diameter. The

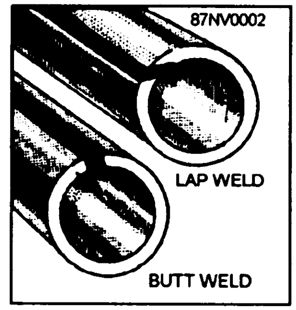


Figure 15-2.—Types of welded pipe construction.

material is beveled or scarfed on the edges, as shown in figure 15-2. First, the material is heated to welding temperature. Then, it is passed over a mandrel and between two grooved rolls that press the lapped edges together, thus forming the welded seam.

Electric-weld processes used in the manufacture of ferrous tubular products include fusion welding and resistance welding. In fusion welding, the butting edges of the material form a V into which the electrode is melted. In resistance welding, the welding heat is generated by the resistance to the flow of an electric current across the seam.

Seamless Processes

The seamless processes used for the manufacture of ferrous and nonferrous tubular products are usually classified as piercing processes and cupping processes.

Piercing processes are used for forming pipe up to 26 inches OD. A solid round bar or billet is heated, pierced, and then worked to the required diameter and wall thickness.

Cupping processes may be used to form pipe between 3 inches and 20 inches OD. The tubular shape is formed by pressing a preheated solid round plate through cupping dies.

CHOICE OF MATERIAL AND SIZES

When you repair any piping system, you will have to be very careful in your selection of materials to be used. First, you need to know what particular type of pipe or tubing is best suited for the fluid it is to carry, and the operating pressures and temperatures the system is to withstand. Second, you must be able to identify the materials that will meet these requirements.

This section will provide general information on the piping and tubing that you will use to work on shipboard piping systems. For details on any specific system, see the ship piping plans (MIL-STD-777) and lists of materials.

SEAMLESS STEEL PIPE is available in standard and extra strong wall thicknesses and comes in lengths of 12 to 22 feet. In the standard wall thickness, it is available in sizes from l/8 inch to 16 inches IPS. Pipe sizes l/8 inch to 3/8 inch come with plain ends, while sizes l/2 inch to 16 inches come with beveled ends for welding. In the extra strong wall thickness, it is available in sizes from 2 inches to 16 inches IPS. It may or may not be galvanized. This pipe is ordinarily stocked with plain ends only. Seamless steel pipe is used aboard ship for diesel exhaust systems, overflow lines, sounding tubes, vents, and air intake systems.

WELDED STEEL PIPE, either galvanized or ungalvanized (black), is also available in standard and extra strong wall thicknesses. In the standard wall thickness, it is available in sizes l/8 inch to 12 inches IPS. The galvanized pipe comes in lengths of 16 to 22 feet, while the ungalvanized pipe comes in lengths of 12 to 22 feet. This pipe comes with beveled ends for welding. The extra strong wall thickness pipe is available in sizes from l/4 inch to 12 inches IPS. It comes in lengths of 12 to 22 feet and is ordinarily stocked with plain ends only. Welded steel pipe is used primarily for general service such as plumbing drain lines aboard ship.

STRUCTURAL STEEL TUBING is supplied in lengths of 12 to 24 feet. This tubing is not intended for pressure applications. It is normally used on such structural jobs as 20mm and 40mm gun mounts and searchlight platforms. Structural tubing made by the seamless processes has a tensile strength of 60,000 psi. The welded structural steel tubing has a tensile strength of 50,000 psi.

SEAMLESS STEEL TUBING is used in oil, steam, and waterline systems. This tubing is available in a variety of types. The type used will depend upon the working pressure and temperature that is to be maintained in the lines.

WELDED STEEL TUBING is available in two types. Their uses are as follows: Type A is used in steam and oil lines where the maximum working pressure is 150 psi. It is also used in water and gas lines that operate at a maximum working pressure of 225 psi. Type B is used in steam lines that operate at a maximum working pressure of 300 psi. It is also used in oil lines that operate at a maximum pressure of 350 psi and in water or gas lines that operate at a maximum pressure of 400 psi.

CARBON MOLYBDENUM (CMO) ALLOY SEAMLESS STEEL TUBING is used in high-pressure steam lines that work at pressures of 401 to 1200 psi and have an operating temperature of 875°F. CMO tubing is used extensively throughout ships' steam systems, but as the piping systems wear out, CMO tubing is being replaced with seamless chromium-molybdenum alloy steel tubing. It is usually used in 600 psi systems. This tubing comes in lengths of 12 to 24 feet.

SEAMLESS CHROMIUM-MOLYBDENUM ALLOY STEEL TUBING is used in high-pressure steam lines that work at pressures of 1201 to 1500 psi and have an operating temperature of 1000°F. This tubing also comes in lengths of 12 to 24 feet.

NONFERROUS TUBING is used for some shipboard piping systems and almost all shipboard heat exchangers. Nonferrous materials are used primarily where corrosion resistance and high heat conductivity are required. Typical shipboard applications of nonferrous tubing are described in the following paragraphs.

Several types of SEAMLESS ALUMINUM ALLOY TUBING are available. Tubing made of the aluminum alloy 6061 is used primarily for dry lines in magazine sprinkling systems. It is also used in some structural applications. Tubing made of the aluminum alloy 5052 is used for bilge and sanitary drain systems.

SEAMLESS BRASS TUBING (semi-annealed and light-annealed) is available in types and sizes suitable for operating pressures that range from 200 psi to 4000 psi. It is used in systems for either fresh water or another fluid. However, it is not approved for any seawater applications. The seamless hard-drawn brass tubing is used for voice and pneumatic tube installations.

SEAMLESS COPPER TUBING is intended for general use aboard ship. If it is not joined by threaded fittings, you may use flanged joints, soldered joints, or flared fittings. Other types of copper tubing are available for various uses such as refrigeration installations, plumbing and heating systems, gasoline systems, lubrication systems, and other shipboard uses.

COPPER ALLOY TUBING is available in a composition of either 70-30 or 90- 10. The first number of the individual composition is the percentage of copper and the second number is the percentage of nickel. Therefore, copper tubing with a 70-30 composition is actually 70 percent copper and 30 percent nickel. Some copper-nickel tubing may be used with Navy brazed tube fittings and butt-welded fittings. However, some types are not suitable for welding, while other types are not suitable for threading. The 70-30 composition has been used for some time in shipboard piping systems and heat exchangers. The Naval Sea Systems Command has authorized the use of the composition 90-10 copper alloy tubing for many applications for which the composition of 70-30 was formerly specified.

PLASTIC as a piping material has not been used to any great extent on naval ships. However, considerable interest has been shown in the Navy's present and future use of plastic piping for naval ships.

Of all the different types of plastic piping material commercially available, two groups have been investigated for shipboard use: (1) glass-reinforced polyester, or epoxy, and (2) polyvinyl chloride (PVC). Of the two types, the polyvinyl chloride has the best all-around characteristics for shipboard use.

PVC plastic piping has a number of advantages. It has an excellent resistance to saltwater corrosion. It is also lightweight, easy to install, and highly resistant to weathering. Some high grades of PVC pipe are highly resistant to shock. As for disadvantages, PVC piping material gives off hydrogen chloride gas when it burns. It cannot be used for carrying high temperature fluids, nor can it be used when surrounding temperatures are high. Due to these disadvantages, plastic piping is not currently used below decks on surface ships. However, PVC plastic piping is currently used in the interim and installed washdown systems aboard naval ships. For more information on plastic piping, refer to NAVSHIPS 250-548-2.

FITTINGS

Every shipboard piping system includes a variety of fittings made from a number of different metals and alloys. They are available in the same size range as the pipe and tubing used in the systems. The layout and the function of a system will determine the composition and the number of fittings used. The use of fittings is held to a minimum because each fitting is a possible source for leaks. However, some fittings are necessary in any piping system. Those normally used in shipboard piping systems are described in this section.

Figure 15-3 shows a variety of common fittings. For example, the return bend shown in view A has the centers of the openings as close together as possible; the elbow shown in view H makes a 90° bend; and the elbow shown in view D makes a 45° bend. This variety in the design of fittings allows you to select' the appropriate fittings for any system.

Some of the plugs, caps, bushings, and nipples used in shipboard piping systems are shown in figure 15-4. Plugs are used to close an opening in fittings or equipment. Caps are used for either temporary or permanent seals of pipe ends. One type of reducing bushing is used to connect two pieces of pipe or tubing together when they have different diameters. Another type is used to connect pipe or tubing to a piece of machinery. Nipples are used for connections to machinery and also in plumbing systems.

A shock-resistant piping nipple is used for root connections to machinery. This type of nipple has straight pipe threads instead of tapered pipe threads. Threaded root connections are used on all ships where piping and equipment are furnished with threaded bosses. A boss on a piece of machinery is a thick-wall socket that is part of the housing. The boss allows the connecting of an external pipe or nipple to the piece of machinery. If existing bosses have tapered pipe threads, it may be possible to retap them for straight pipe threads. Otherwise, it will be necessary to use a nipple with tapered threads. In this case, you must be careful when fitting the nipple to ensure that the gasket is compressed correctly and that the tapered threads are tightly seated. However, you should avoid the use of tapered thread nipples whenever possible.

Union fittings, and valves that have union ends, are used in piping systems to simplify repairs or alterations (fig. 15-5). The number of fittings and valves should be kept to a minimum and checked periodically for leaks.

Unions are available in bronze, iron, and steel, and are designed to withstand a wide range of temperatures and pressures. Bronze unions come in sizes up to 2 1/2 inches. Iron and steel unions (galvanized or black) come in sizes up to 3 inches. The straight, branch elbow, and run types of bronze unions are capable of withstanding 250 psi pressure. The union bulkhead fitting is designed for 3000 psi water, oil, or gas lines that pass through bulkheads.

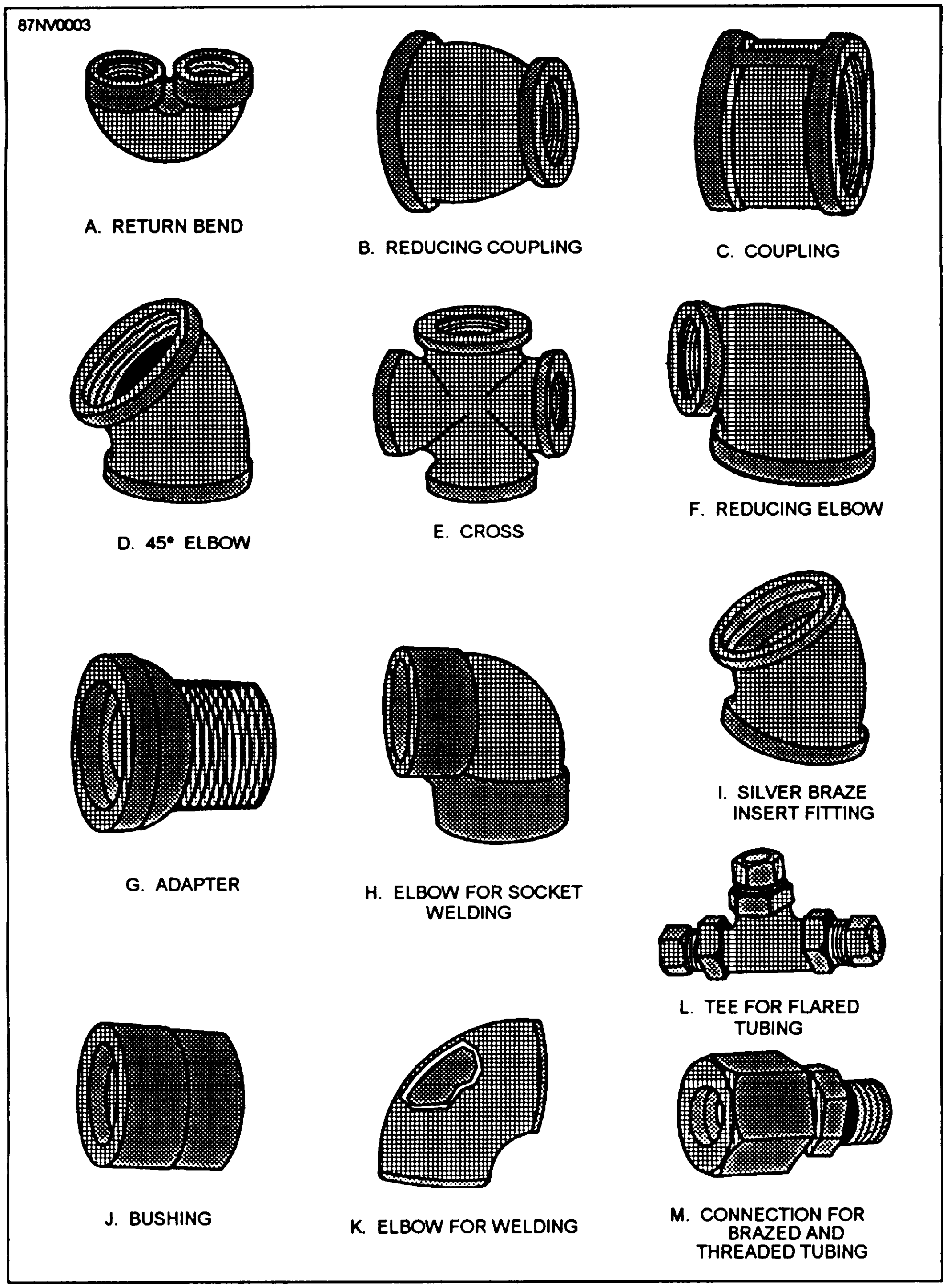


Figure 15-3.—Typical pipe fittings.

Another type of union is the malleable iron flange union shown in view A of figure 15-6. This union flange is intended for 150 psi steam lines, and is available in sizes up to 6 inches, galvanized or black.

The socket welded flange shown in view G of figure 15-6 is suitable for various services, pressures, and temperatures. This flange is slipped onto the pipe end and fillet-welded in place.

The Van Stone flange, shown in view H of figure 15-6, is used in high-pressure steam lines that are subjected to high temperatures and to expansion strains. It consists of a regular flanged upper portion and a

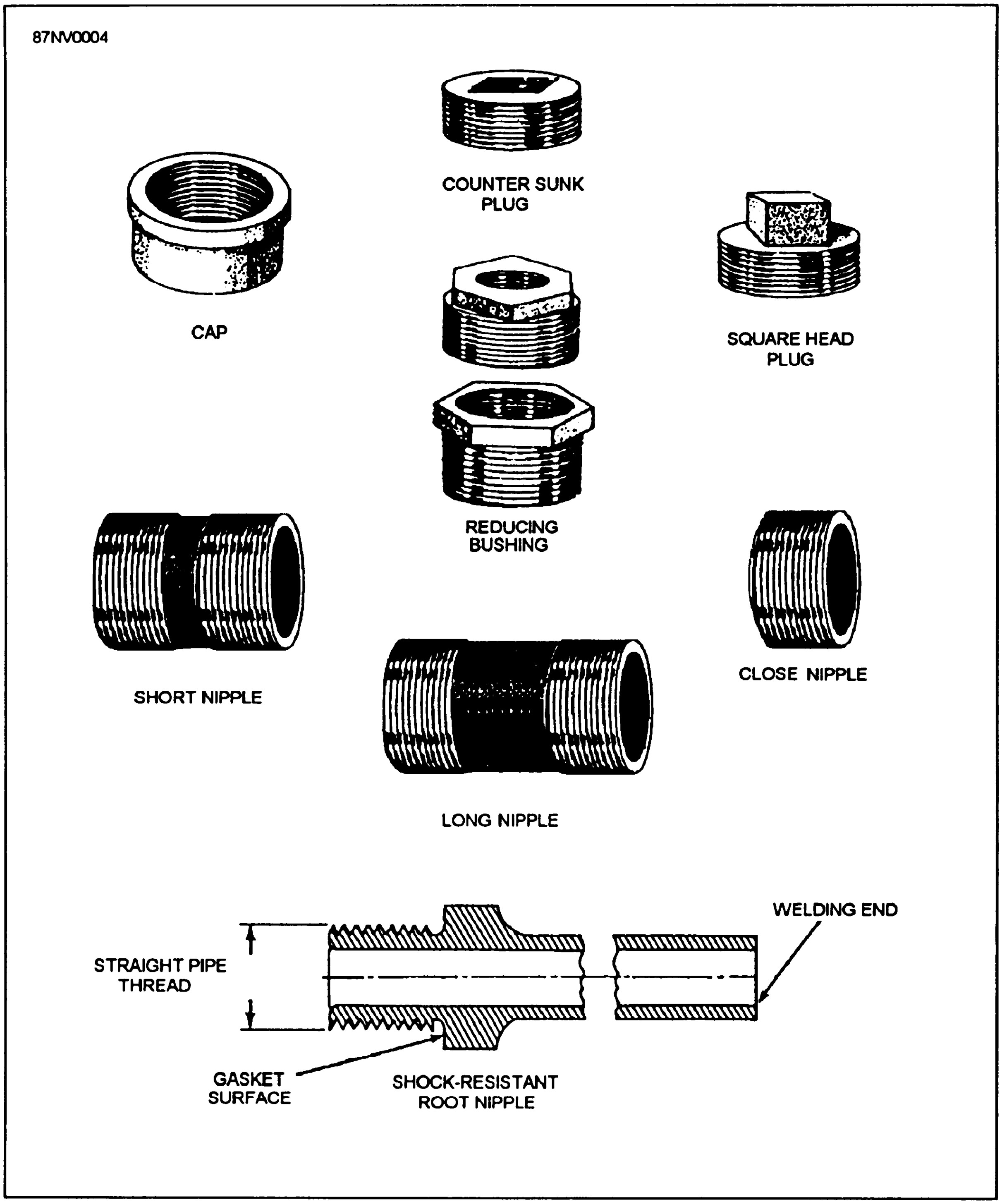


Figure 15-4.—Nipples, plugs, cap, and bushing.

ground lower portion, allowing for a leakproofjoint that will align itself when the flange bolts are tightened.

Flanges can be attached to pipes and tubing by welding, brazing, rolling, flaring, or (in some low-pressure systems) with screw threads. The method used will depend upon the size of pipe and the service of the system in which it is installed. It will also depend upon the construction period of the ship. The piping system index will give you useful information on this point. Flanged joints are sealed by the use of special gasket materials. The gasket materials will be discussed later in this chapter.

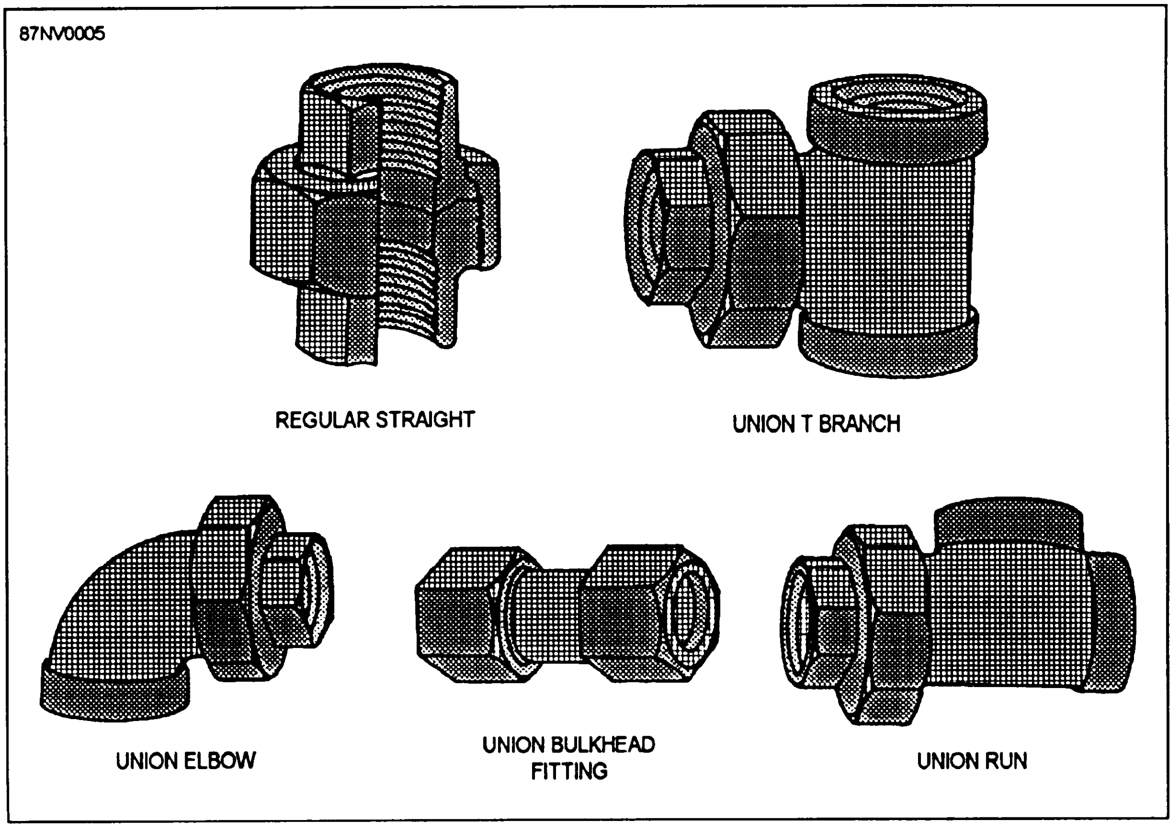


Figure 15-5.—Unions.

VALVES

Every piping system must have some means to control the amount and direction of the flow of liquids or gas through the lines. This is accomplished by installing valves, which can be opened or closed as required.

Valves are usually made of bronze, brass, cast or malleable iron, or steel. Steel valves are either cast or forged, and are made of carbon steel, low ahoy steel, or stainless steel. Alloy steel valves are used in high-pressure, high-temperature systems. The disks and seats of these valves are usually surfaced with a chromium-cobalt alloy known as stellite. This material is extremely hard.

Bronze and brass valves are not used in high-temperature systems, or in any system in which they would be exposed to severe pressure, vibration, or shock. Bronze valves are widely used in saltwater systems. The seats and disks of bronze valves used for saltwater service are often made of Monel, which is highly resistant to corrosion and erosion.

Many different types of valves are used to control the flow of liquids and gases. As described in *Fireman,* NAVEDTRA 12001, there are two main groups of valves: stop valves and check valves. Stop valves are used to shut off (or, in some cases, to partially shut off) the flow of fluid. These valves are controlled entirely by the movement of the valve stem. Check valves are used to permit the flow of fluid in one direction only. These valves are controlled by the movement of the fluid itself.

Valve designs vary considerably because of the different demands of services. Some valves are combinations of the more or less basic type just mentioned. Special valves, such as reducing valves, bear only a slight resemblance to the basic types. However, stop valves may include globe valves, gate valves, piston valves, plug valves, needle valves, and butterfly valves. Check valves may include swing-check valves and lift-check valves.

GLOBE VALVES

Globe valves are one of the most common types of stop valves. They get their name from the globular shape of their bodies. However, other types of valves may also have globe-shaped bodies, so do not jump to the conclusion that a valve with a globe-shaped body is

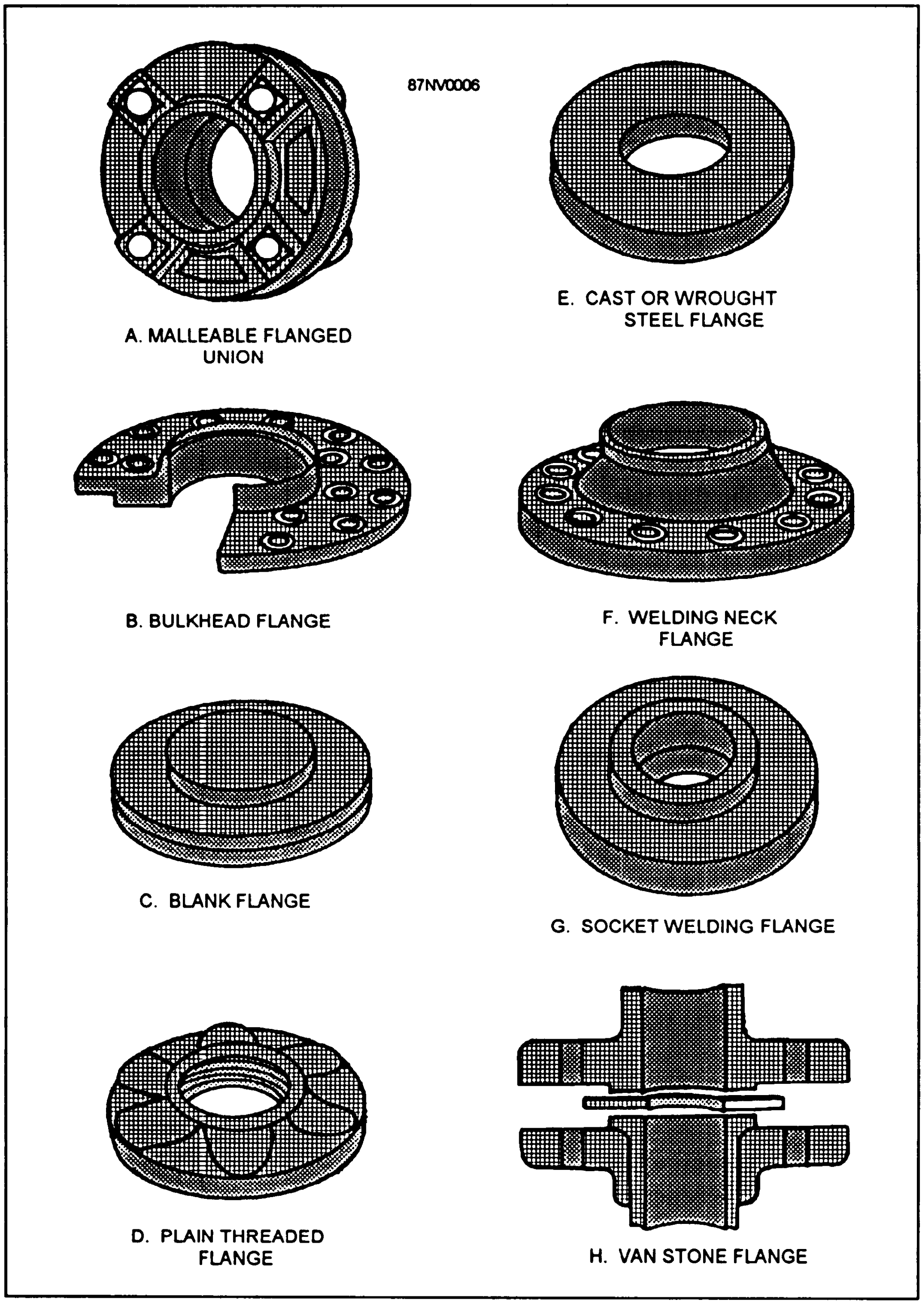


Figure 15-6.—Flanges.

actually a globe valve. The internal structure of a valve, not the external shape, is what distinguishes one type of valve from another.

In a globe-type stop valve, the disk is attached to the valve stem. The disk scats against a seating ring or a seating surface and therefore shuts off the flow of fluid. When the disk is removed from the seating surface, fluid can pass through the valve in either direction. Globe valves may be used partially open as well as fully open or fully closed.

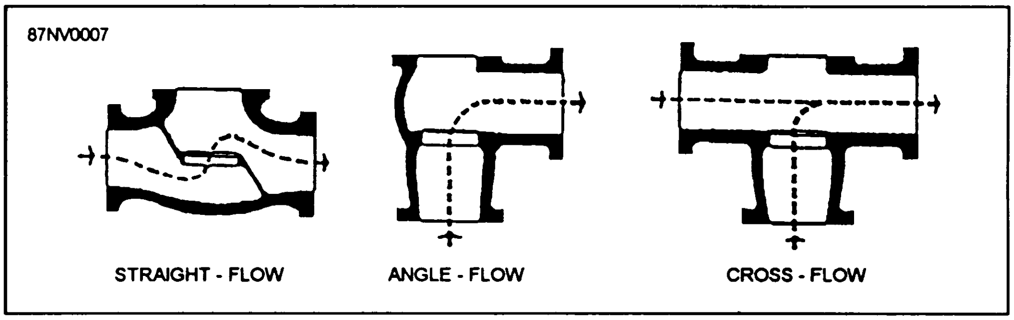


Figure 15-7.—Types of globe valve bodies.

Globe valve inlet and outlet openings are arranged in several ways to satisfy different requirements of flow. Figure 15-7 shows three common types of globe valve bodies. In the straight type, the fluid inlet and outlet openings are in line with each other. In the angle type, the inlet and outlet openings are at an angle to each other. An angle-type globe valve is commonly used where a stop valve is needed at a 90° turn in a line. The cross-type globe valve has three openings rather than two; it is frequently used in connection with bypass lines.

Globe valves are commonly used in steam, air, oil, and water lines. On many ships, you will find surface blow valves, bottom blow valves, boiler stops, feed stop valves, and many guarding valves and line cutout valves. Globe valves are also used as stop valves on the suction side of many fireroom pumps, as recirculating valves in the fuel oil system, and as throttle valves on most fireroom auxiliary machinery.

A cutaway view of a globe stop valve is shown in figure 15-8.

GATE VALVES

Gate valves are used in systems where a straight flow with the least amount of restriction is needed. Figure 15-9 is a cross-sectional view of a gate valve. You will find that most of the firemain cutout valves are gate valves. These valves are also used in steam lines, water lines, and fuel oil lines.

The part of a gate valve that serves the same purpose as the disk in a globe valve is known as the gate. The gate is normally wedge-shaped. However, some are uniform in thickness throughout. When the gate is wide open, the opening through the valve is equal to the size of the piping in which the valve is installed. Therefore, there is very little resistance in the flow of the liquid and also very little pressure reduction caused by the gate valve. Since regulating the flow of liquid would be difficult and could cause extensive damage to the valve, the gate valve is not to be used as a throttling valve.

The gate is connected to the valve stem. Turning the handwheel will raise or lower the valve gate. Some gate valves have nonrising stems. On these, the stem is threaded on the lower end and the gate is threaded on the inside. Therefore, the gate will travel up the stem when the valve is being opened. This type of valve will

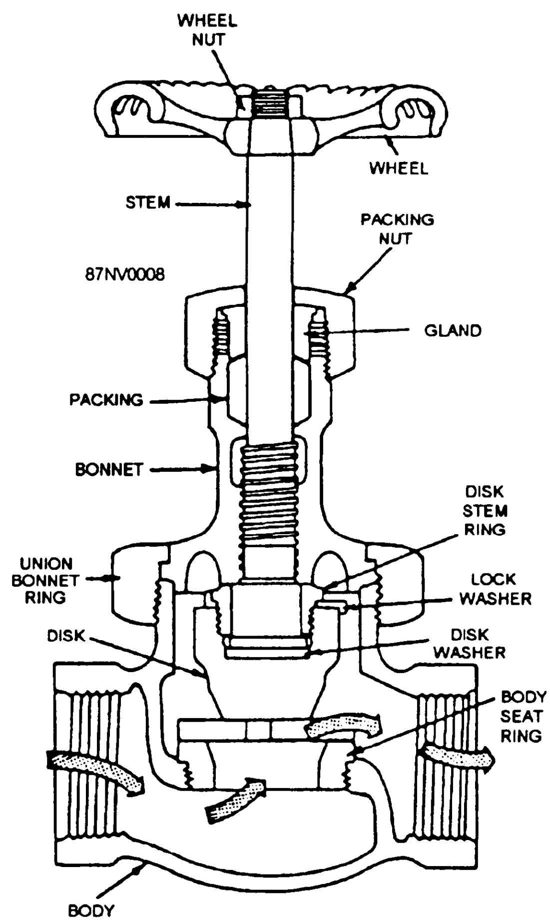


Figure 15-8.—Cutaway view of a globe stop valve.

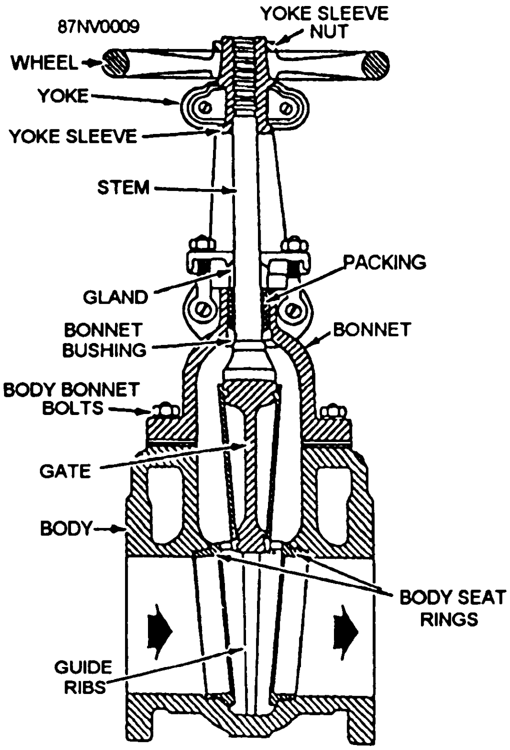


Figure 15-9.—Cross-sectional view of a gate stop valve rising stem.

usually have a pointer or a gauge to indicate whether the valve is in the open or closed position. Some gauge valves have rising stems. In these valves, both the gate and stem will move upward when the valve is opened. In some rising stem valves, the stem will project above the handwheel when the valve is opened.

BUTTERFLY VALVES

The butterfly-type valve (fig. 15-10) in certain applications has some advantages over gate and globe valves. The butterfly valve is lightweight, takes up less space than a gate valve or globe valve, is easy to overhaul, and can be opened or closed quickly.

The design and construction of butterfly valves may vary, but a butterfly-type disk and some means of sealing are common to all butterfly valves.

The butterfly valve shown in figure 15-10 consists of a body, a resilient seat, a butterfly-type disk, a stem, packing, a notched positioning plate, and a handle. The resilient seat is under compression when it is mounted in the valve body. The compression causes a seal to form around the edge of the disk and both upper and lower points where the stem passes through the seat. Packing is provided to form a positive seal around the stem if the seal formed by the scat is damaged.

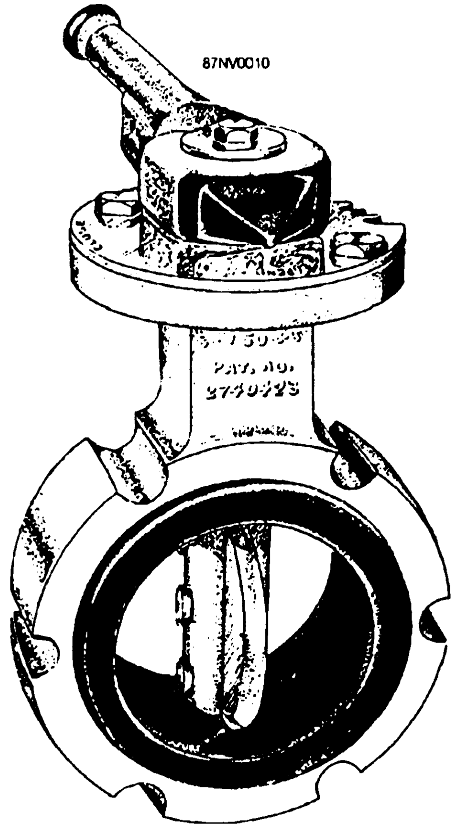


Figure 15-10.—Butterfly-type valve.

To close the valve, turn the handle a quarter of a turn to rotate the disk 90°. The resilient seat exerts positive pressure against the disk, which assures a tight shutoff.

You will find that butterfly valves are easy to maintain. The resilient seat is held in place by mechanical means. Therefore, neither bonding nor cementing is necessary. Since the resilient seat is replaceable, the valve seat will not require any lapping, grinding, or machine work.

Butterfly valves serve a variety of requirements. These valves are now being used in freshwater, saltwater, JP-5 fuel, Navy special fuel oil, diesel oil, and lubricating oil systems.

CHECK VALVES

Check valves permit liquids to flow through a line in one direction only. For example, they are used in drain lines where it is important that there is no backflow. Considerable care must be taken to see that valves are properly installed. Most of them will have an arrow, or the word *INLET*, cast on the valve body to indicate direction of flow. If not, you will have to check

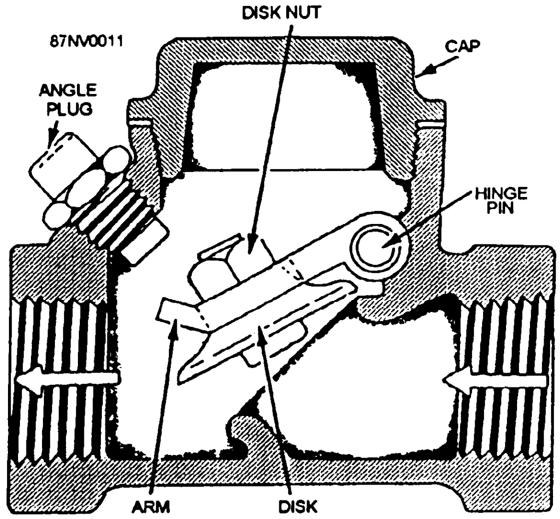


Figure 15-11.—Swing-check valve.

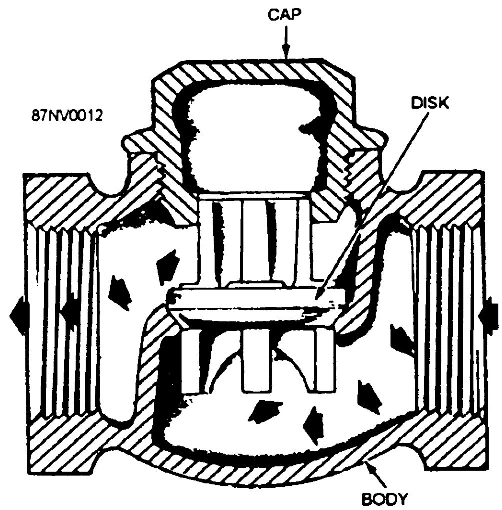


Figure 15-12.—Lift-check valve.

closely to make sure that the flow of the fluid in the system will operate the valve in the proper manner.

The port in a check valve may be closed by a disk, a ball, or a plunger. The valve opens when the pressure on the inlet side is greater than that on the outlet side. The valves also open and close automatically. They are made with threaded, flanged, or union faces, with screwed or bolted caps, and for specific pressure ranges.

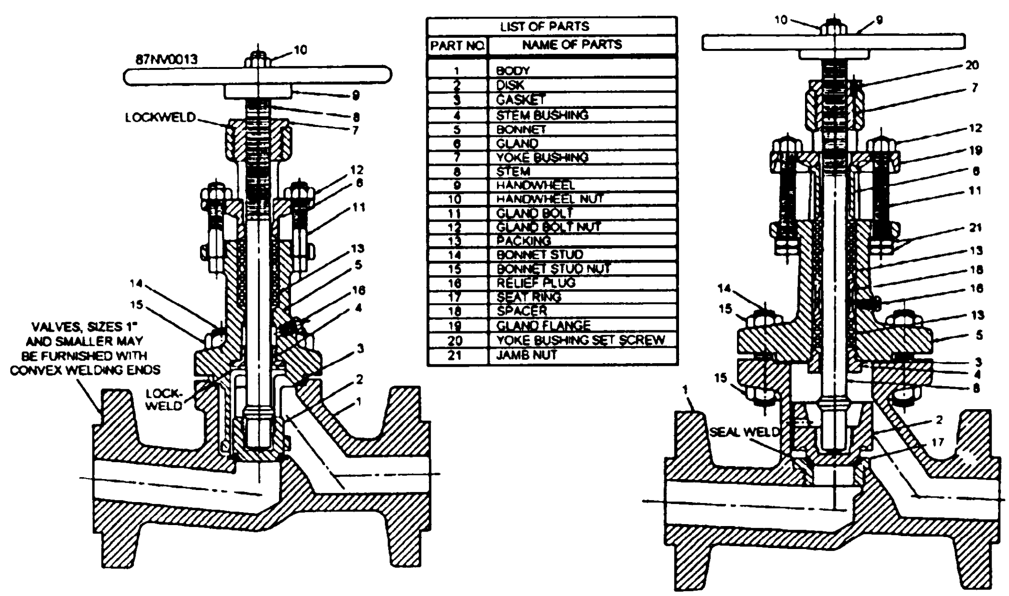
The disk of a swing-check valve (fig. 15-11) is raised as soon as the pressure in the line below the disk is of sufficient force. While the disk is raised, continuous flow takes place. If for any reason the flow is reversed, or if back pressure builds up, this opposing pressure will force the disk to scat, which in turn stops the flow.

The operation of a lift-check valve (fig. 15-12) is basically the same as that of the swing-check valve. The difference is that the valve disk moves in an up-and-down direction instead of through an arc.

STOP-CHECK VALVES

As we have seen so far, most valves may be classified as either stop valves or check valves. However, some valves function either as a stop valve or as a check valve, depending upon the position of the valve stem. These valves are known as stopcheck valves.

The cross section of two stop-check valves is shown in figure 15-13. As you can see, this type of



LIST OF PARTS	
PART NO.	NAME OF PARTS
1	BODY
2	DISK
3	GASKET
4	STEM BUSHING
5	BONNET
6	GLAND
7	YOKE BUSHING
8	STEM
9	HANDWHEEL
10	HANDWHEEL NUT
11	GLAND BOLT
12	GLAND BOLT NUT
13	PACKING
14	BONNET STUD
15	BONNET STUD NUT
16	RELIEF PLUG
17	SEAT RING
18	SPACER
19	GLAND FLANGE
20	YOKE BUSHING SET SCREW
21	JAMB NUT

Figure 15-13.—Stop-check valves.

valve looks very much like a lift-check valve. However, the valve stem is long enough so that when it is screwed all the way down it holds the disk firmly against the seat, thereby preventing the flow of any fluid. In this position, the valve acts as a stop valve. When the stem is raised, the disk can then be opened by pressure on the inlet side. In this position, the valve acts as a check valve and allows the flow of fluid in one direction only. The amount of fluid allowed to pass through is regulated by the opening. The opening is adjusted by the stem.

PRESSURE-REDUCING VALVES

Pressure-reducing valves are automatic valves that are used to provide a steady pressure lower than that of the supply pressure. Pressure-reducing valves can be set for any desired discharge pressure that is within the limits of the design.

There are several types of reducing valves in the Navy. However, you will be working mostly with those in the flushing system. These will normally be single-seated, direct-acting, and spring-loaded, as shown in figure 15-14. Water passing through this valve is controlled by means of a pressure difference on both sides of the diaphragm. The diaphragm is secured to the stem. Reduced water pressure from the valve outlet is then led through an internal passage to a diaphragm chamber that is located below the diaphragm. An adjusting spring acts on the upper side of the diaphragm. A leather cup washer or a neoprene O-ring makes the water seal between the valve inlet and the diaphragm chamber. This seal is located halfway down the valve stem.

The amount of water pressure applied to the underside of the diaphragm varies according to the discharge pressure. When the discharge pressure is greater than the spring pressure, the diaphragm is forced up. Since this is an upward-seating valve, the upward movement of the stem tends to close the valve or at least to decrease the amount of discharge. When the discharge pressure is less than that of the spring pressure, the diaphragm and the valve stem are forced down, opening the valve wider and increasing the amount of discharge. When the discharge pressure is equal to the spring pressure, the valve stem will remain stationary and the flow of water through the valve is not changed.

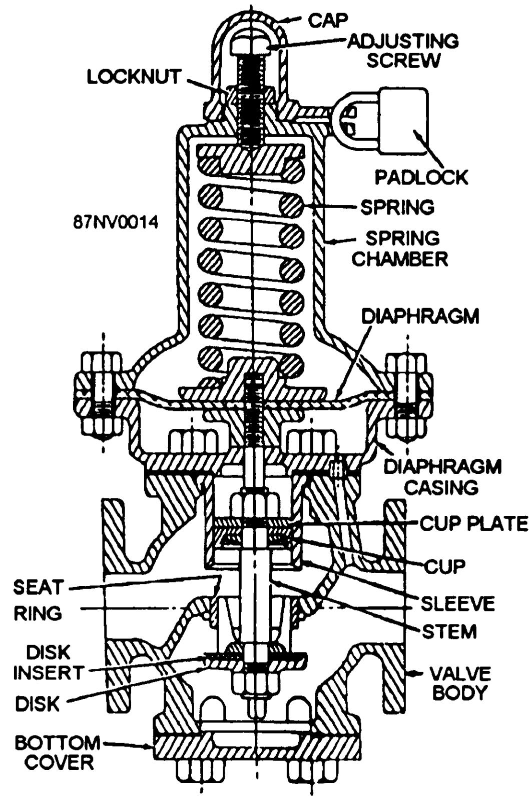


Figure 15-14.—Spring-loaded, diaphragm-type pressure-reducing valve.

The amount of pressure applied by the spring to the top of the diaphragm can be adjusted by turning an adjusting screw. Turning the adjusting screw clockwise will increase the pressure applied by the spring to the top of the diaphragm, which in turn opens the valve. Turning the adjusting screw counterclockwise will decrease the amount of spring pressure on top of the diaphragm, which in turn decreases the amount of discharge.

The opening and closing of the valve will continue as long as the discharge pressure fluctuates. For example, when a water closet is flushed, the pressure drops in the supply line. This line is on the discharge side of the pressure-reducing valve. Therefore, the diaphragm will move down and open the valve. As the flushometer closes, the pressure builds up again and closes the reducing valve.

PNEUMATIC-PRESSURE-CONTROLLED REDUCING VALVES

There are two types of the pneumatic-pressure-controlled (or gas-loaded) reducing valve. One type regulates low-temperature fluids, such as air, water, or oil (fig. 15-15). The other type (not shown) regulates high-temperature fluids, such as steam or hot water. The high-temperature fluid reducer is found only in older ships.

Air-controlled regulators operate on the principle that the pressure of an enclosed gas varies inversely to its volume. A reduction in volume results in an immediate increase in pressure. Conversely, an increase in volume results in an immediate decrease in pressure. A relatively small change in the large volume within the dome loading chamber produces only a slight pressure variation, while the slightest variation in the small volume within the actuating chamber creates an enormous change in pressure. The restricting orifice connecting these two chambers governs the rate of pressure equalization by retarding the flow of gas from one chamber to the other.

The dome loading chamber is charged with air or other compressible gases (such as nitrogen) at a pressure equal to the desired reduced pressure. When the chamber is loaded and when the loading valve is closed, the dome will retain its charge almost indefinitely. When the regulator is in operation, the trapped pressure within the dome passes into the actuating chamber through the small separation plate orifice. This pressure moves the large flexible diaphragm, which forces the reverse-acting valve off its seat. The pressure entering the regulator is then permitted to flow through the open valve into the reduced pressure line. A large pressure equalizing orifice transmits this pressure directly to the underside of the diaphragm. When the delivered pressure approximates the loading pressure in the dome and the unbalanced forces equalize, the valve will close. With

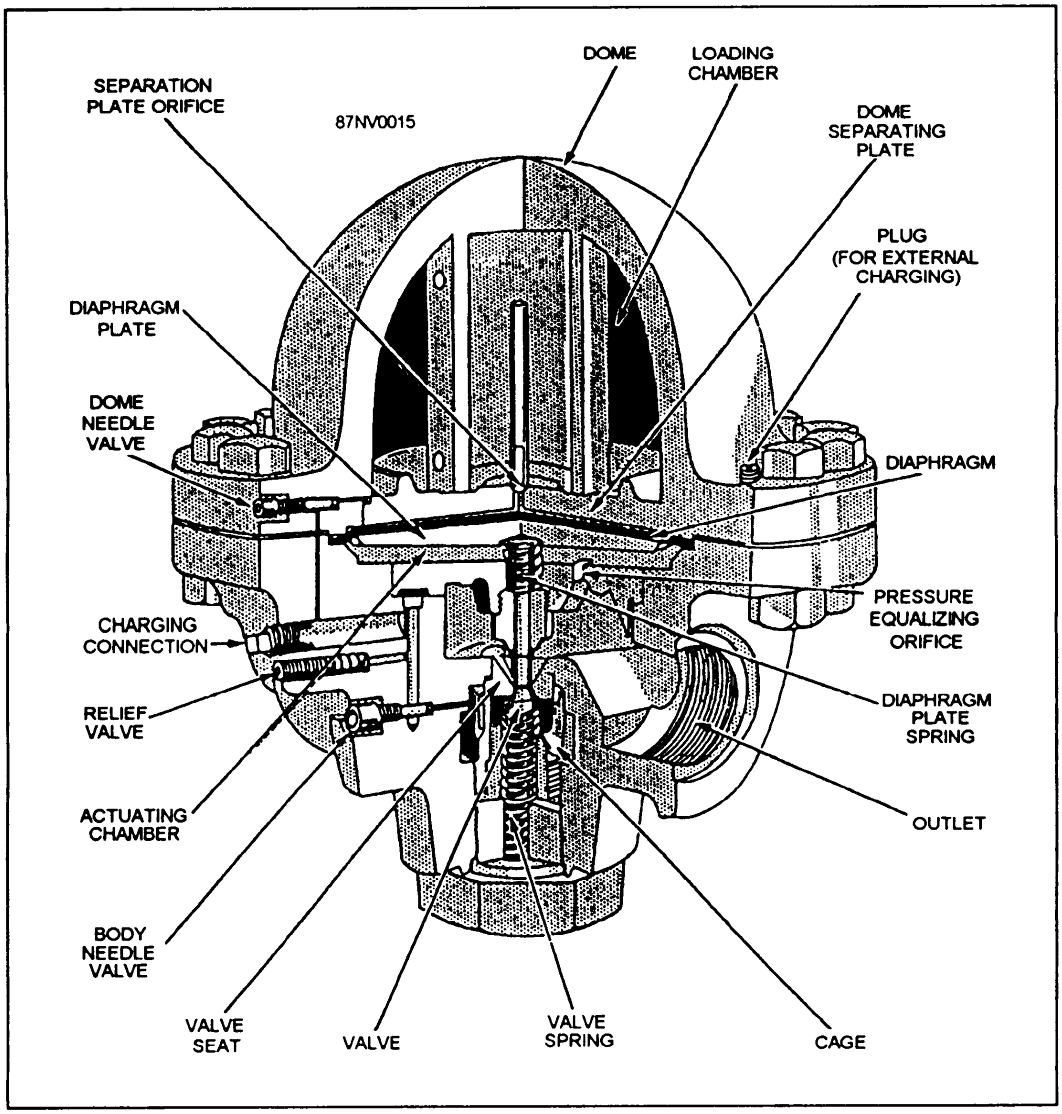


Figure 15-15.—Pneumatic-pressure-controlled reducing valve for low-temperature service.

the slightest drop in delivered pressure, the pressure charge in the dome instantly forces the valve open. This allows system fluid to pass through, thereby maintaining the outlet pressure relatively constant.

To charge the loading chamber, back off slightly on the dome needle valve. Connect the specially furnished hand pump (either 300 or 600 psi), and fill the dome to the desired outlet pressure. If the regulator is to handle a gas, charge the dome loading chamber with this gas via the dome needle valve and the body needle valve (fig. 15-15). If the regulator is to handle a liquid, charge the dome from an external source. Remove the plug on the dome loading chamber and connect the external source. This may be an air bottle or an air pump. Keep the body needle valve closed while you use the dome needle valve to adjust the dome pressure to obtain the desired outlet pressure.

HYDRAULIC CONTROL VALVES

Hydraulic control valves are used in many shipboard systems. On some ships, they are installed in the sections of firemain that supply water to the magazine sprinkling systems. This type of valve may be operated from one or more remote control stations by a hydraulic control system.

The hydraulic control valve shown in figure 15-16 is a piston-operated globe valve. It is normally held in the closed position by both a spring force and by the firemain pressure acting against the disk. When hydraulic pressure is admitted to the underside of the piston, a force is created that overcomes both the spring tension and the firemain pressure, thereby causing the valve to open.

When hydraulic pressure is released from under the piston, the spring acts to force the hydraulic fluid out of the cylinder and back to the remote control station, thus closing the valve.

A ratchet lever is fitted to the valve to allow the emergency opening of the valve by hand. After the valve has been opened by hand, you should first restore the stem to its normal CLOSED position with the ratchet lever. Then line up the hydraulic system from a remote control station so that the hydraulic fluid in the valve cylinder can return to the storage tank at the control station. The full force of the closing spring then acts to seat the disk, thereby closing the valve.

The valve shown in figure 15-16 is equipped with a test casting in the body of the valve. The bottom cover

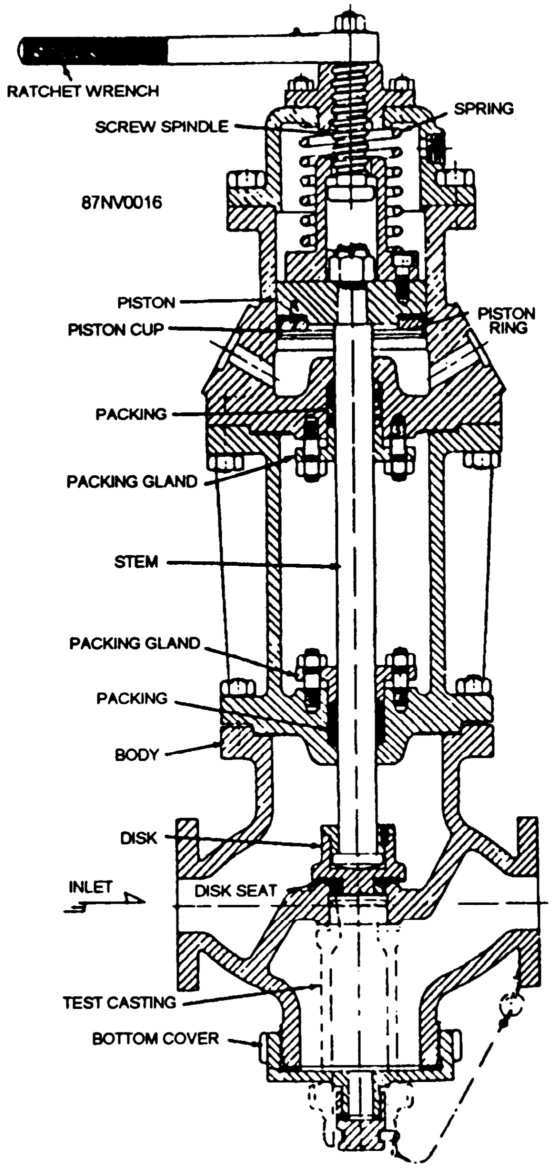


Figure 15-16.—Hydraulic control valve.

can be removed so that you can check the valve for leakage.

TRAPS AND STRAINERS

Traps are used to remove various undesirable materials from piping systems. In air lines, a trap is installed to remove the water that is usually present. In steam lines, traps are installed to remove condensate. Some types of steam traps are suitable for low-pressure use, while others are suitable for high-pressure use. However, any steam trap will consist of a valve and some device or arrangement that will cause the valve to open and close, as necessary to drain the condensate from the lines without allowing steam to escape. The

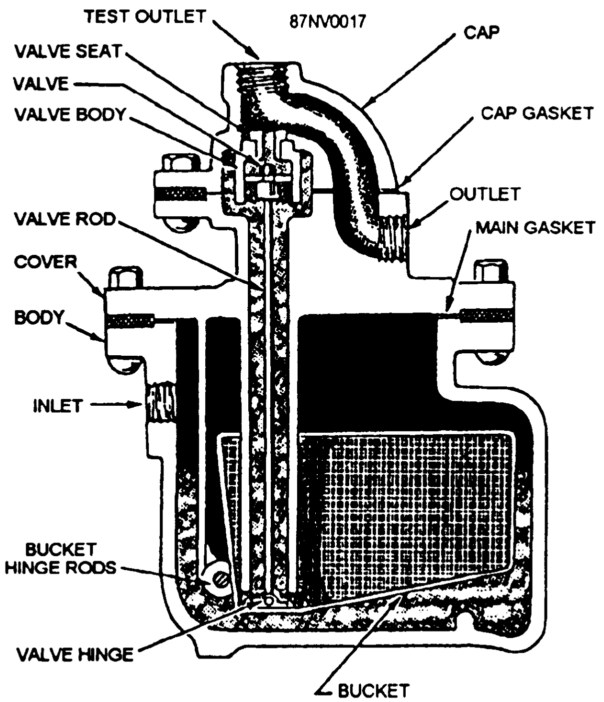


Figure 15-17.—Bucket-type steam trap.

three types of steam traps most commonly used are (1) mechanical, (2) thermostatic, and (3) flash, or impulse. You will be concerned primarily with the mechanical and the thermostatic types.

Mechanical steam traps may be of the ball float type or of the bucket type, which is suitable only for low-pressure use. The bucket-type steam trap (fig. 15-17) is suitable for pressures up to 150 psi. Operation of these traps is regulated by the condensate level in the trap body. The bucket, being buoyant, floats as condensate enters the trap body. The valve is connected to the bucket and therefore closes as the bucket rises. As condensate continues to flow into the trap body, the valve will remain closed until the bucket is filled. When the bucket is filled, it sinks and causes the valve to open. The valve will remain open until enough condensate is blown out to allow the bucket to float, thus closing the valve.

The thermostatic-type steam trap shown in figure 15-18 is often called a bellows-type steam trap. This type of steam trap has fewer moving parts, and is more compact than the mechanical steam traps just described. The bellows-type trap is used only for pressures up to 100 psi. Its operation is controlled by the expansion of vapor from a volatile liquid that is enclosed in a bellows-type element. Steam enters the trap body and heats the volatile liquid in the sealed bellows, which causes the expansion of the bellows. The valve is attached to the bellows, and therefore closes when the bellows expands. The valve remains closed and traps the steam in the trap body. Condensation of the steam then cools the bellows and causes it to contract; the valve then opens and allows the condensate to drain.

Figure 15-19 shows three types of lavatory traps. In views A and B, the P-type lavatory trap is shown with and without a cleanout plug. View C shows the S-type trap specified for shipboard use. This latter type, equipped with cleanout plug, is supplied only in 1 l/2-inch IPS. However, S-type traps without cleanout plugs are available in 1 l/4-inch, 1 l/2-inch, and 2-inch

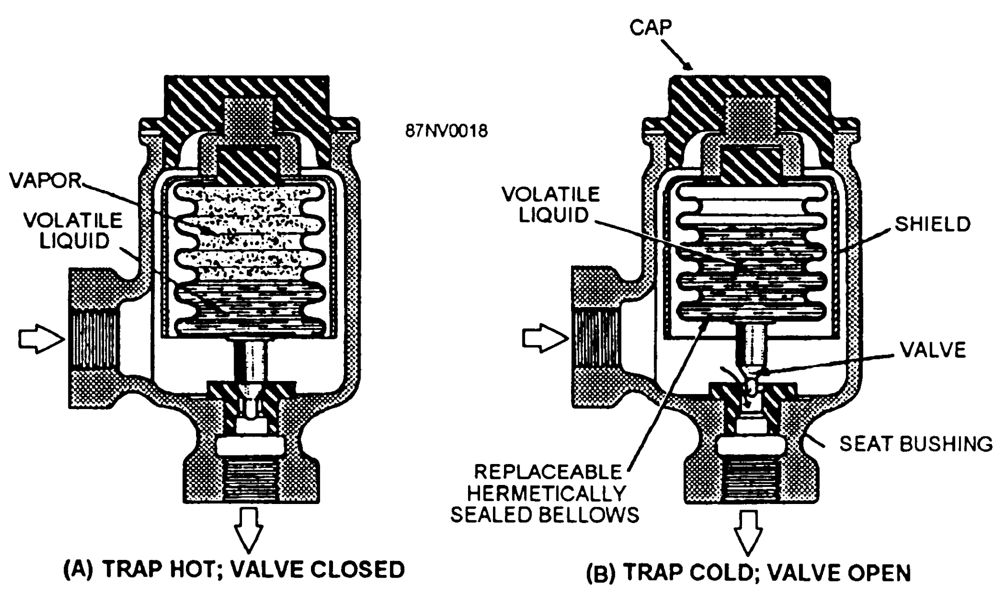


Figure 15-18.—Thermostatic steam trap.

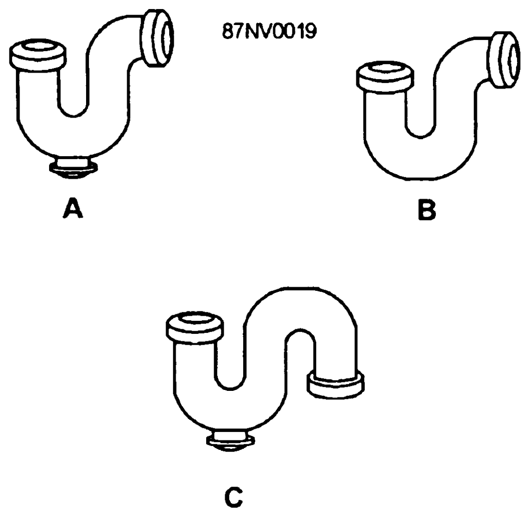


Figure 15-19.—Lavatory traps.

IPS, with inlet sizes of 1 l/4, 1 l/2, 2, or 2 l/2 inches. The 1 l/2-inch inlet trap is the one most commonly used for lavatories. These fittings are made from brass and are usually chrome plated. The lavatory trap acts as a check valve for the drainage system. The water that collects in the trap prevents se wage gases from escaping through the drain into the compartment where the fixture is located.

The deck drains shown in figure 15-20 are made from brass, and have a 2-inch IPS outlet. These types are used in tiled heads and washrooms. At shore stations, however, a combination drain and P-type trap made from cast iron is used extensively. It consists of a drain inlet, a drain outlet, and a P-type trap, all cast in one assembly, and with a clamping ring and a brass strainer disk completing the unit. This type of drain and trap assembly comes in two sizes. One has a 6-inch

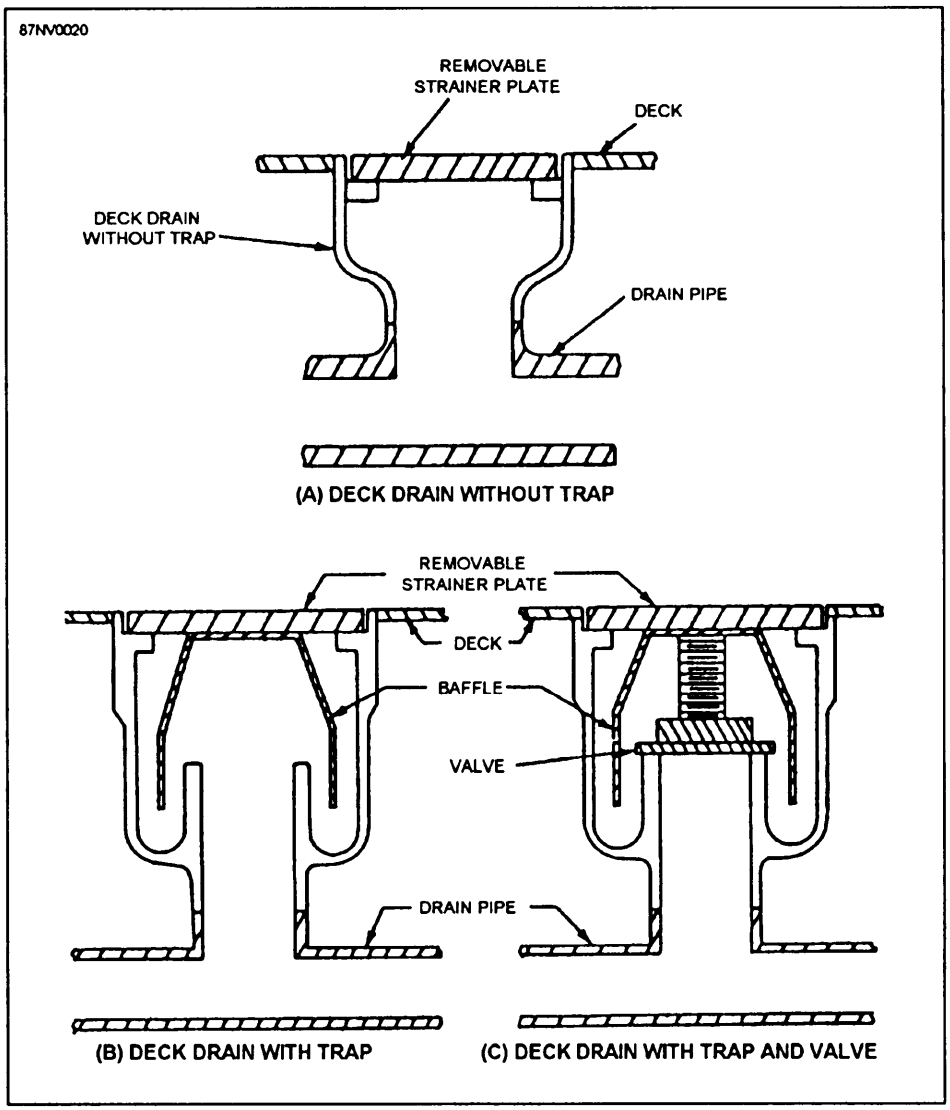


Figure 15-20.—Typical deck drains.

drain inlet and a 2-inch IPS outlet. The other has an 8-inch drain inlet and a 3-inch IPS outlet.

Strainers are located in all piping lines to prevent the passage of foreign matter. They must be installed so that the flow will be through the strainer element. The bilge suction strainer (fig. 15-21) is an example of a basket strainer. Some systems use duplex strainers. The duplex strainers allow the fluid to continue flowing while one of the strainers is removed for cleaning. Therefore, you do not need to secure the system to clean the strainers.

IDENTIFICATION OF VALVES, FITTINGS, FLANGES, AND UNIONS USING THE MANUFACTURERS STANDARDIZATION SOCIETY (MSS) MARKING SYSTEM

Many valves, fittings, flanges, and unions used on naval ships are marked with some sort of identification symbol. Valves and fittings made on board repair ships and tenders, or at naval shipyards are usually marked with symbols indicating the manufacturer (the ship's number or the insignia of the naval shipyard), the size, the pattern number, the melt or casting number, and the material. They may also be marked with the date (year) of manufacture and with an arrow signifying the direction of flow.

Many commercially manufactured valves, fittings, flanges, and unions are identified according to a standard marking system developed by the Manufacturers Standardization Society (MSS) of the

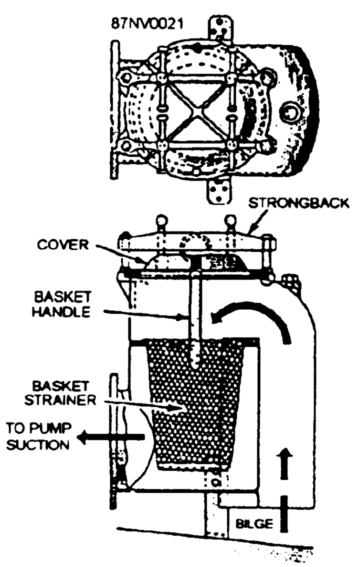


Figure 15-21.—Basket strainer.

valves and fittings industry. A standard identification marking in this system usually includes the manufacturer's name or trademark, the pressure and service for which the product is intended, and the size (in inches). When appropriate, material identification, limiting temperatures, and other identifying data are included.

The MSS standard identification markings are generally cast, forged, stamped, or etched on the exterior surface of the product. However, in some cases, the markings are applied to an identification plate rather than to the actual surface of the product.

The service designation in the MSS system of marking usually includes a letter to indicate the type of service and numerals to indicate the service pressure rating in pounds per square inch. The letters used in service designations are A (air), G (gas), L (liquid), O (oil), W (water), and D-W-V (drainage, waste, and vent).

When the primary service rating is for steam, and when no other service is indicated, the service designation may consist of numerals only. For example, the number 600 marked on the body of a valve would indicate that the valve is suitable for steam service at 600 psi. If the valve is designed for liquid at 600 psi, the service designation would be 600 L. Service designations are also used in combination; for example, the marking 3000 WOG would indicate a product suitable for water, oil, or gas service at 3000 psi.

In the MSS marking system, the material designation may be either spelled out or abbreviated. Most cast, wrought, or forged steel products are marked with the word STEEL. Malleable iron is identified by the abbreviation MI on newer products. On older products, the abbreviation MAL or MALL is used. Ductile cast iron is identified by the word *DUCTILE* or by the abbreviation DI. Other symbols used for material identification include the following:

AL . . . . Aluminum

B . . . . Bronze

CS . . . . Carbon steel

CI . . . . Cast iron

HF . . . . Cobalt-chromium-tungsten alloy (hard facing)

CU NI . . . . Copper-nickel alloy

NI CU . . . . Nickel-copper alloy

SM	Soft metal (lead, babbitt, copper, and so on)
CR 13	13 percent chromium steel
CR 18	18 percent chromium steel
18 8	18-8 stainless steel
18 8SMO	18-8 stainless steel with molybdenum
18 8SCB	18-8 stainless steel with columbium
SH	Surface-hardened steel (Nitralloy, and so on)

Some examples of the MSS standard identification marking symbols are given in figure 15-22.

Systems may also be identified by their stencils and color codes. You will find information on the requirements for stenciling and color coding of pipes and valves in the *NSTM*, chapter 505, and the *General Specifications for Ships of the United States Navy*, section 507. Table 15-2 gives you the color codes and paint chip numbers, and table 15-3 is a list of the basic color codes for valve handwheels for the systems with which you will be involved.

PACKING AND GASKET MATERIALS

Packing and gasket materials are required to seal joints in steam, water, gas, air, oil, and other lines. They are also used to seal connections that slide or rotate

3-INCH CAST STEEL SCREWED FITTING SUITABLE FOR WATER, OIL, OR GAS SERVICE AT 1000 PSI: Manufacturer's identification . . . . . . A B CO Service designation . . . . 1000 WOG Material designation . . . . STEEL Size 3	2-INCH CAST IRON FLANGED FITTING FOR USE IN REFRIGERATION SYSTEM: Manufacturer's identification . . . . . . A B CO Service designation . . . . 300 GL Temperature designation . . . . 300°F Size 2
CAST BRASS FITTING FOR DRAINAGE, WASTE, AND VENT SERVICE: Manufacturer's identification . . . . . . A B CO Service designation . . . . D-W-V	2-INCH BRONZE VALVE RECOMMENDED BY THE MANUFACTURER FOR 200 PSI STEAM SERVICE: Manufacturer's identification . . . . . . A B CO Service designation . . . . 200 Size 2

4-INCH STEEL VALVE WITH 13 PERCENT CHROMIUM STEEL VALVE STEM, DISK, AND SEAT, SUITABLE FOR 1500 PSI STEAM SERVICE AT TEMPERATURE OF NO MORE THAN 850°F:

VALVE BODY MARRING:
Manufacturer's identification . . . . A B CO
Service designation 1500
Material designation . . . . STEEL
Size . . . .

IDENTIFICATION PLATE MARRING:
Manufacturer's identification . . . . A B CO
Service designation 1500
Limiting temperature . . . . MAX 850°F
Body material designation . . . . STEEL
Valve stem material designation . . . . STEM CR 13
Valve disk material designation . . . . DISC CR 13
Valve seat material designation . . . . SEAT CR 13
Size 4

Figure 15-22.—Examples of MSS standard identification markings for valves, fittings, flanges, and unions.

Table 15-2.—Color Codes for Valves and Piping

Fluid	Valve Handwheel and Operating Lever	FED STD 595 Color Number and chip
Steam and Steam Drams	white	17886
Potable Water	Dark Blue	15044
Nitrogen	Light Gray	16376
HP Air	Dark Gray	16081
LP Air	Tan	10324
Oxygen	Light Green	14449
Seawater (other than firemain, sprinkling, and washdown)	Dark Green	14062
JP-5	Purple	17141
Fuel Oil	Yellow	13538
Lube oil	Striped Yellow/Black	13538/17038
Fire Plugs	Red	11105
Foam Discharge Plugs (AFF)	Striped Red/Green	11105/14062
Gasoline	Yellow	13538
Feedwater	Light Blue	15200
Hydraulic	Grange	12246
Freon	Dark Purple	17100
Hydrogen	Chartreuse	23814
Amine	Brown	10080
Helium	Buff	10371
Helium/Oxygen	Striped Buff/Green	10371/14449
Sewage	Gold	17043
HALON	Striped Gray/White	16187/17886
Firemain (including root valves)	Red	11105
AFFF	Striped Red/Green	11105/14062

* Applies to valves on weather decks and interior piping only.

Table 15-3.—Color Codes for Valve Handwheels

Valve Handwheels	Color Code
Access fittings	Black
Fresh water	Blue
Firefighting equipment	Red
Freon and lithium bromide	Purple
Fuel and lube oil	Yellow
High-pressure air	Standard gray (dark)
Hydraulic	Grange
Hydrogen	Yellow-green (chartreuse)
Low-pressure air and salvage air	Tan
Moroethanolamine	Brown
Nitrogen	French gray (light)
Oxygen	Light green
Saltwater	Green
Steam	White

under operating conditions. There are many commercial types and forms of packing and gasket material. The Navy has simplified the selection of packing and gasket materials commonly used in naval service. The Naval Sea Systems Command has prepared a packing and gasket chart (Mechanical Standard Drawing B0153, Rev 9). This chart shows the symbol numbers and the recommended applications of all types and kinds of packing and gasket materials. A copy of the chart should be located in all engineering spaces.

A four-digit symbol number identifies each type of packing and gasket. The first digit indicates the class of service with respect to fixed and moving joints. For example, if the first digit is 1, it indicates a moving joint (moving rods, shafts, valve stems, and so forth). If the first digit is 2, it indicates a fixed joint (such as a flange or a bonnet). The second digit indicates the material of which the packing or gasket is primarily composed. This may be asbestos, vegetable fiber, rubber, metal, and so on. The third and fourth digits indicate the different styles or forms of the packing or gaskets made from the material.

Practically all shipboard packing and gasket problems can be solved if the correct material is selected from the listings on the packing and gasket chart.

CAUTION

NEVER use low-pressure packing in place of high-pressure packing; however, some high-pressure packing may be used to repack low-pressure steam valves.

The following examples show the kind of information you can get from the packing and gasket chart.

Suppose you are required to repack and install a valve in a 300-psi saturated steam line. By referring to the packing and gasket chart, you will find several materials that are suitable for repacking the valve:

Symbol 1103	Asbestos rod, braided, plain
Symbol 1104	Asbestos rod, braided, wire insertion
Symbol 1430	Metallic, flexible

Notice that the first digit is 1 in each case, to indicate that the packing is suitable for a moving joint.

To install a valve, you will need suitable gaskets. In this case, the first digit will be 2, indicating that the gasket material is suitable for fixed joints. By referring to the packing and gasket chart, you will find that you can use any of the following gasket materials:

Symbol 2150	Asbestos, sheet, compressed
Symbol 2151	Asbestos, metallic, cloth sheet
Symbol 2410	Gasket, metallic, asbestos, spiral wound

In addition to the standard packing and gasket chart, most ships have a packing and gasket chart made up specifically for that ship. The shipboard chart shows the symbol numbers and the sizes of packing and gaskets required in the ship's piping systems, machinery, and hull fittings.

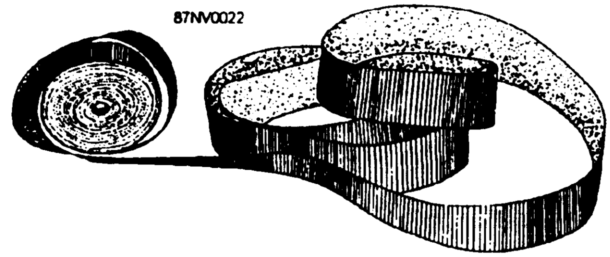


Figure 15-23.—Corrugated ribbon packing.

PACKING

Corrugated ribbon packing (CRP) is a relatively new packing material; it is a 100 percent graphite material expressly suited for installation in steam, feed, and condensate valves. CRP (fig. 15-23) contains no binders, resins, fillers, lubricants, or other additives. It has the lubricating quality typical of pure graphite with the capability for rapid heat dissipation, thus reducing wear. Unlike conventional graphite, which is brittle, CRP is flexible and highly resilient. When CRP is formed in a valve stuffing box, it restructures as shown in figure 15-24.

This restructuring capability allows CRP to be wrapped around the valve stem in any size valve stuffing box and to be formed into a ring by compression. It forms a solid endless packing ring when it is compressed.

CRP is easily cut to a predetermined length. It does not turn rock hard or shrink at any temperature. Once installed and after run-in, it normally needs no further adjustment. This means that maintenance is greatly reduced. The resiliency and no-lint structure of CRP remain unchanged at any temperature. There is no lubricant or additive to be squeezed out, vaporized, or carbonized. Also, it has a long shelf and service life.

WARNING

CRP conducts electricity. Identification and warning stickers must be clearly visible on all containers to assure prevention of its use for electrical insulation.

Use CRP with anti-extrusion rings made of graphite filament yarn (GFY) packing. Install the rings at the bottom (first ring) and at the top (last ring) of every stuffing box. Set the GFY to prevent the CRP from being forced out of the stuffing box (extruded) through

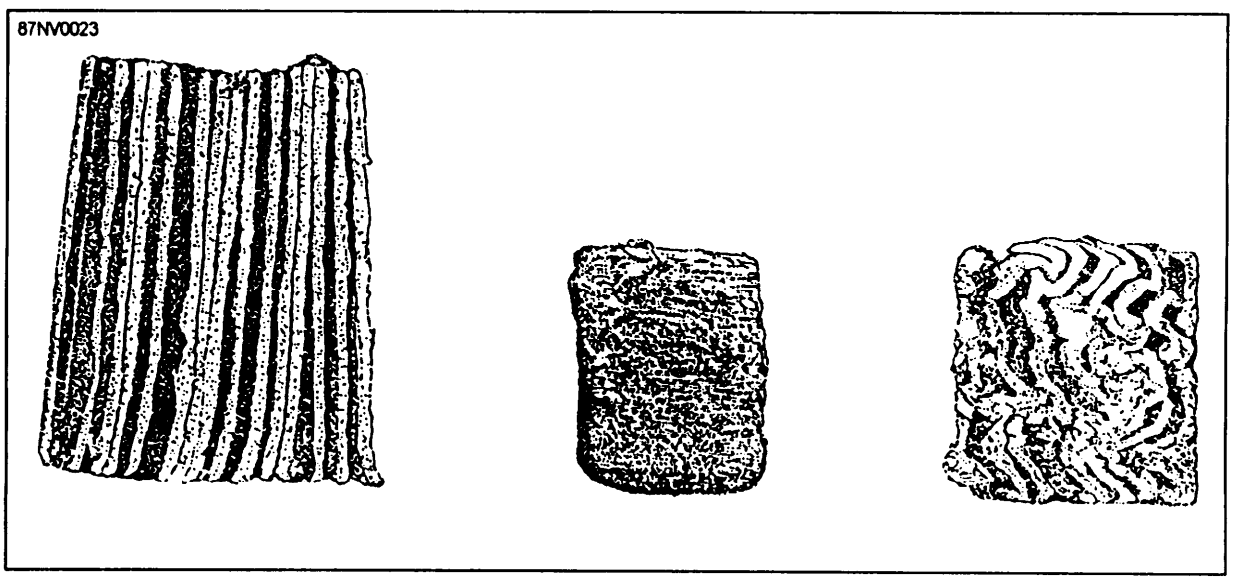


Figure 15-24.—Sectional views of corrugated ribbon packing after restructuring.

stem-stuffing, stem-gland, and gland-stuffing box clearances.

If GFY is not available, you can install a ring of conventional packing as anti-extrusion rings. However, the use must be temporary. At the earliest opportunity, disassemble, inspect, and repack the valve using GFY anti-extrusion rings with CRP.

GFY packing, figure 15-25, is a severe service packing ideal for use in difficult fluid-handling applications. It is unaffected by the most destructive corrosive fluid substances. It will withstand extreme temperatures of over 1000°F encountered in valve stuffing boxes. GFY packing is self-lubricating. It has exceptional heat dissipation characteristics. This allows tight packing adjustment to make leakage almost nonexistent. It also provides maximum protection against stem scoring. This packing greatly reduces system fluid loss, maintenance, and downtime to provide longer, trouble-free valve life. GFY is available in sizes from l/8 inch to 1 inch square on spools.

NOTE: Regardless of how good the packing material may be, if the surface of the shaft passing through the stuffing box is scored or damaged in any way, the packing will not last long. When replacing packing, carefully inspect the shaft in the area where it passes through the stuffing box. Inspect the interior of the stuffing box itself. Take whatever steps you can to ensure that the packing will make contact with the straightest, smoothest possible surface. (You may have to have the shaft repaired and refinished, or replaced.)

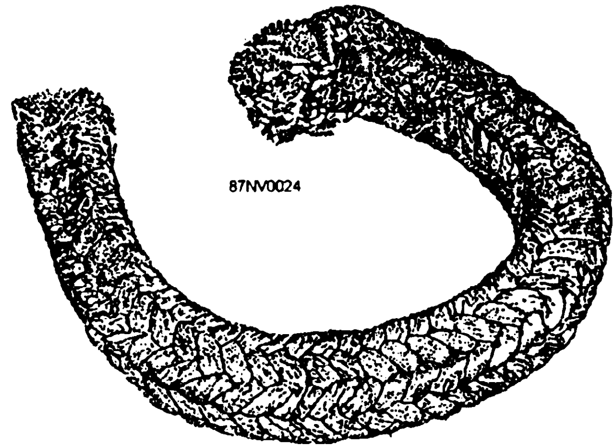


Figure 15-25.—Graphite filament yarn.

GASKETS

At one time, fixed steam joints could be satisfactorily sealed with gaskets of compressed asbestos sheet packing (fig. 15-26, view A). However,

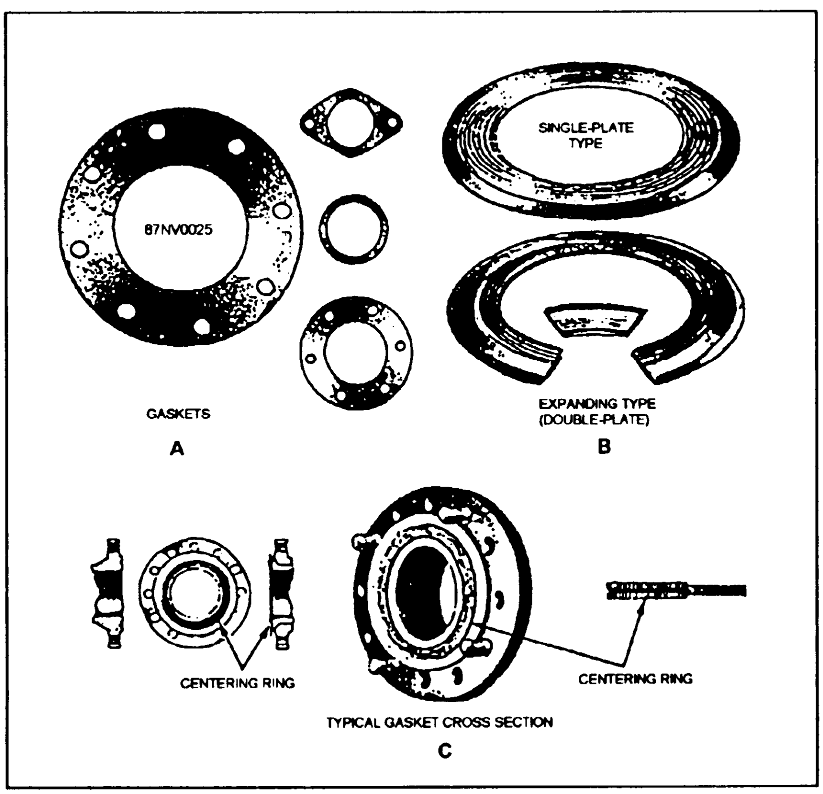


Figure 15-26.—Fixed joint gaskets. A. Sheet gaskets. B. Serrated-face metal gasket. C. Spiral-wound metallic gasket.

the 15 percent rubber content of the gasket makes it unsatisfactory for modem high-temperature steam equipment. Gaskets of corrugated copper or of asbestos and copper are sometimes used on low- and medium-pressure lines. The serrated-face metal gasket (view B) and the spiral-wound metallic gasket (view C) are used in present-day high-temperature, high-pressure installations.

Plain Full-Faced Gaskets

When cutting a plain full-faced gasket from compressed gasket sheet, lay an appropriate size piece of the gasket sheet on the flange. Scribe in the bolt holes and flange circle lines with light blows of a ball peen hammer. Using a gasket punch, about l/16 inch larger in diameter than the bolts, cut the bolt holes into the gasket material Use a piece of hardwood as the supporting and backing surface for the material while punching it to prevent damage to the lips of the punch. After the holes have been punched, use shears or a sharp knife to cut the center and outside circles to form the ring.

Serrated-Face Metal Gasket

Serrated-face metal gaskets (fig. 15-26, view B) are made of steel, Monel, or soft iron. They have raised serrations to make a better seal at the piping flange joints. These gaskets have resiliency; line pressure tends to force the serrated faces tighter against the adjoining flange. Two variations of serrated-face metal gaskets are shown: the single-plate type and the expanding type (double-plate).

Spiral-Wound Metallic Gaskets

Spiral-wound metallic gaskets (fig. 15-26, view C) are made of two parts. The first is interlocked piles of preformed corrugated metal and paper strips, spirally wound, called a filler. The second is a solid metal outer or centering ring, sometimes called a retaining ring. The filler piece is replaceable. When renewing a gasket, remove the filler piece from the retaining metal ring and replace it with a new refill. Do not discard the solid metal retaining outer ring unless it is damaged. Then place the gasket into a retainer or centering ring. The solid steel centering also acts as reinforcement to prevent blowouts. The gaskets can be compressed to the thickness of the centering ring.

Precautions

When renewing a gasket in a flanged joint, use special precautions. When breaking the joint, particularly in steam and hot water lines, or in saltwater lines that have a possibility of direct connection with the sea, be sure of the following conditions:

1. There is no pressure on the line.
2. The line pressure valves, including the bypass valves, are firmly secured, wired closed, and tagged.
3. The line is completely drained.
4. At least two flange-securing bolts and nuts diametrically opposite remain in place until the others are removed. These bolts are then slackened to allow breaking of the joint. They are removed after the line is clear.
5. Precautions are taken to prevent explosions or fire when breaking joints of flammable liquid lines.
6. Proper ventilation is ensured before joints are broken in closed compartments.

These precautions may prevent serious explosions, severe scalding of personnel, or flooding of compartments. Thoroughly clean all scaling and bearing surfaces for the gasket replacement. Then check the gasket seats with a surface plate. Scrape as necessary to ensure uniform contact. Replace all damaged bolt studs and nuts. In flanged joints that have raised faces, the edges of gaskets may extend beyond the edge of the raised face.

PACKING PRECAUTIONS

Observe the following general precautions with regard to the use of packing:

1. Do NOT use metallic or semimetallic packing on bronze or brass shafts, rods, plungers, or sleeves. If these materials are used, scoring may result. Use a braided packing that is lubricated throughout. Or, use a nonmetallic plastic packing in the center of the box with an end ring of the braided packing at each end of the box.
2. Do NOT use a packing frictioned with rubber or synthetic rubber of any kind on rotary or centrifugal shafts. Such packing will overheat.
3. Do NOT use braid-over-braid packing on rotary or centrifugal shafts. The outer layer will wear

through quickly and eventually the packing will become rags.

4. Do NOT use packing with a rubber binder on rotary-type compressors. It will swell and bind, thereby developing excessive frictional heat. The use of flexible metallic packing is recommended. Or, you may use a lead-base plastic packing alternated with the flexible metallic packing.

5. On hydraulic lifts, rams, and accumulators, use a V-type packing or O-ring. For water, this packing should be frictioned with crude, reclaimed, or synthetic rubber. For oils, the packing should be frictioned with oil-resistant synthetic rubber.

6. Do NOT use a plastic packing, such as symbol 1433 or 1439, alone on worn equipment or out-of-line rods; it will not hold. Use a combination of 1433 with end rings of plain braided asbestos (1103) or flexible metallic packing (1430). These will be satisfactory for temporary service until defective parts can be repaired or replaced.

7. Do NOT use a soft packing against thick or sticky liquids or against liquids having solid particles. This packing is too soft to hold back liquids, such as cold boiler fuel oil, and it usually gets torn. Some of the solid particles may be suspended in these liquids. They will embed themselves in the soft packing. These particles then act as an abrasive on the rod or shaft. Flexible metallic packing is best for these conditions.

INSULATION

The purpose of insulation is to retard the transfer of heat FROM piping that is hotter than the surrounding atmosphere or TO piping that is cooler than the surrounding atmosphere. Insulation helps to maintain the desired temperatures in all systems. In addition, it prevents sweating of piping that carries cool or cold fluids. Insulation also protects personnel from being burned by hot surfaces. Piping insulation is the composite piping covering that consists of the insulating material, lagging, and fastening. The insulating material offers resistance to the flow of heat. The lagging, usually of painted canvas, is the protective and confining covering placed over the insulating material. The fastening attaches the insulating material to the piping and to the lagging.

Insulation covers a wide range of temperatures. They range from the extremely low temperatures of the refrigerating plants to the very high temperatures of the ship's boilers. No one material could possibly be used to meet all the conditions with the same efficiency.

The following quality requirements for the various insulating materials are taken into consideration by the Navy in the standardization of these materials:

- Low heat conductivity
- Noncombustibility
- Lightweight material
- Easy molding and installation capability
- Moisture repellent
- Noncorrosive, insoluble, and chemically inactive
- Composition, structure, and insulating properties unchanged by the temperatures at which it is to be used
- Once installed, it should not cluster, become lumpy, disintegrate or build up in masses from vibration
- Verminproof
- Hygienically safe to handle

Insulating material is available in preformed pipe coverings, blocks, batts, blankets, and felts. *NSTM*, chapter 635, contains all of the insulating materials, along with their application and precautions.

INSULATION AND CEMENTS

The insulating cements are composed of a variety of materials. They differ widely among themselves as to the conductivity, weight, and other physical characteristics. Typical variations are the asbestos cements, diatomaceous cements, and mineral and slag wool cements. These cements are less efficient than other high-temperature insulating materials. However, they are valuable for patchwork emergency repairs and for covering small irregular surfaces, such as valves, flanges, and joints. The cements are also used as a surface finish over block or sheet forms of insulation, to seal joints between the blocks, and to provide a smooth finish over which asbestos or glass cloth lagging may be applied (fig. 15-27).

Removable insulation is usually installed in the following locations:

- Manhole covers, inspection openings, turbine casing flanges, drain plugs, strainer cleanouts, and spectacle flanges
- Flanged pipe joints adjacent to machinery or equipment that must be broken when units are opened for inspection or overhaul
- Valve bonnets of valves larger than 2 inches NPS that operate at 300 psi and above, or at 240°F and above
- All pressure-reducing and pressure-regulating valves, pump pressure governors, and strainer bonnets

A small unit of machinery or equipment, such as an auxiliary turbine, requires a different approach. It would be difficult to install both permanent insulation over the casing and removable and replaceable covers over the casing flanges. Therefore, the entire insulation may be made removable and replaceable. Covers should fit accurately and should project over adjacent permanent insulation.

Observe the following general precautions in the application and maintenance of insulation:

1. Fill and seal all air pockets and cracks. Failure to do this will cause large losses in the effectiveness of the insulation.
2. Seal the ends of the insulation and taper off to a smooth, airtight joint. At joint ends or other points where insulation is liable to damage, use sheet metal lagging. Cuff flanges and joints with 6-inch lagging.
3. Keep moisture out of all insulation work. Moisture is an enemy of heat insulation fully as much as it is of electrical insulation. Any dampness increases the conductivity of all heat-insulating materials.
4. Insulate all hangers and other supports at their point of contact from the pipe or other unit they are supporting. Otherwise, a considerable quantity of heat will be lost via conduction through the support.
5. Keep sheet metal covering bright and unpainted unless the protecting surface has been damaged or has worn off. The radiation from bright-bodied and light-colored objects

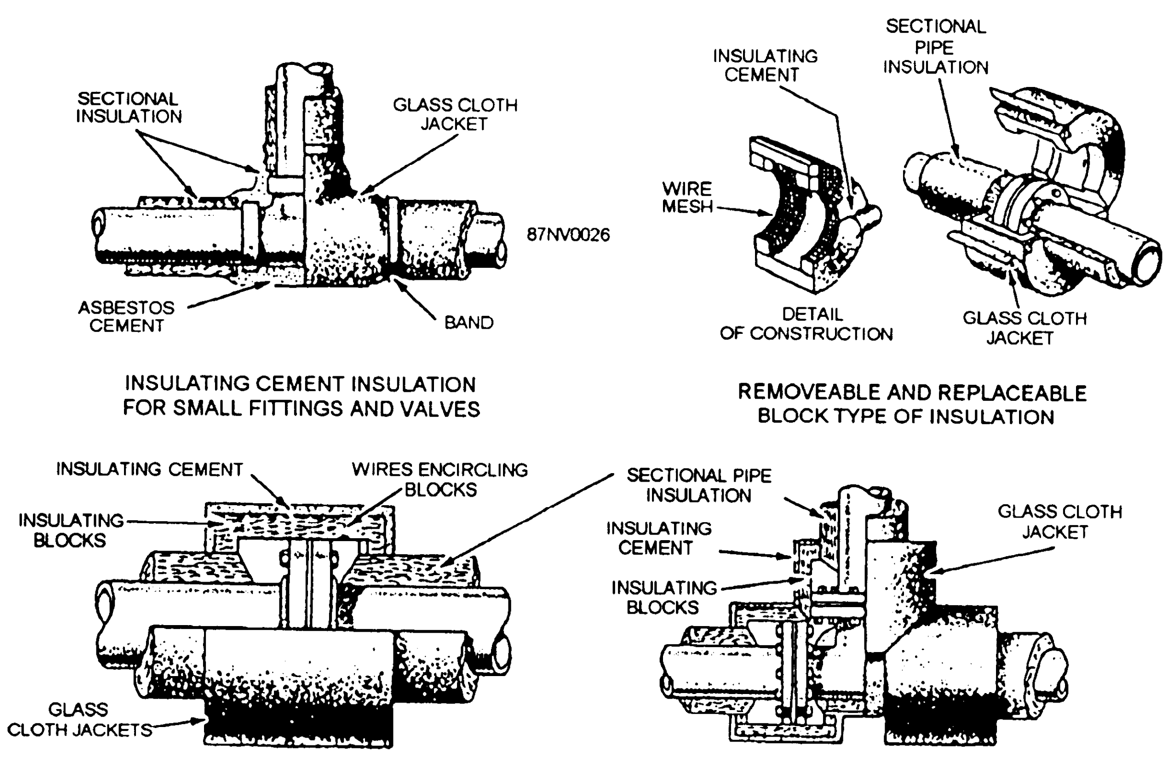


Figure 15-27.—Permanent-type insulation of pipe fittings, flanges, and valves.

is considerably less than from rough and dark-colored objects.

6. Carefully inspect, provide upkeep, and repair heat insulation once it is installed. Replace lagging and insulation removed to make repairs just as carefully as when it was originally installed. When replacing insulation, make certain that the replacement material is the same type that had been used originally.

7. Insulate all flanges with easily removable forms. These can be made up as pads of insulating material, wired or bound in place. The whole can be covered with sheet metal casings that are in halves and easily removed.

The main steam, auxiliary steam, auxiliary exhaust, feedwater, and steam heating piping systems are lagged to hold in the heat. The circulating drainage, fire, and sanitary piping systems are lagged to prevent condensation of moisture on the outside of the piping.

> **CAUTION**
>
> Lagging and insulation should be considered to contain asbestos unless certified not to contain it. Do not rip out asbestos lagging without a respirator or stay in the area of the ripout if you are unprotected. Inhaled asbestos tiller can cause severe lung damage in the form of disabling or fatal fibrosis of the lungs. Asbestos has also been found to be a causal factor in the development of cancer of the membrane lining the chest and abdomen. Lung damage and disease usually develop slowly and often do not become apparent until years after the initial exposure. Ripping out or handling asbestos is restricted to the trained emergency asbestos removal team or an intermediate maintenance activity (IMA). *NSTM*, chapter 635, and chapter B1 of OPNAVINST 5100.19B, *NAVOSH Program Manual for Forces Afloat*, include asbestos removal precautions and procedures.

PIPING SYSTEMS

Piping systems aboard ship are used to carry steam, salt water, fresh water, fuel oil, lubricating oil, gasoline, air, and many other fluids. All piping systems serve the same basic purpose, to transfer fluids from one place to another. An individual piping system may be used strictly for one type of fluid, or it may be used for several different types of fluids at separate times.

As a Hull Maintenance Technician, you will require some knowledge of most of the piping systems on board ship. The rest of this chapter will present some general information on the properties and characteristics of fluids and a general description of the most common piping systems on board ship.

GENERAL CHARACTERISTICS OF FLUIDS

The term *fluid* includes liquids, gases, and vapors. Fluids have no shape of their own. They will quickly conform to the shape of the container they are in, and they are easily pumped through piping systems.

Both gases and vapors are gaseous substances, but they differ in the ease with which they can be liquified. If a large change in pressure or temperature is required to liquefy a substance, it is called a gas. If a relatively small change in pressure, or temperature, changes a substance to a liquid, the substance is called a vapor. Air is an example of a gas. Steam is normally considered a vapor. When steam is superheated, however, it may be considered a gas rather than a vapor.

There are considerable variations in the properties of the liquids, gases, and vapors carried by shipboard piping systems. Some of these properties will be discussed briefly in the following paragraphs.

The property of compressibility is the main basis by which different liquids are distinguished from each other, and also by which gases are distinguished from vapors. It is almost impossible to compress liquids, but gases and vapors can be compressed rather easily. When a force is applied to a confined liquid, the liquid will act almost like a solid by transmitting a force equally in all directions. This example will show that water is not easily compressed: If a force of 15 pounds of pressure is applied to 1 cubic inch of water, the volume of the water will decrease only l/20,000 of what it was. Other liquids have similar resistance to compression. A liquid’s resistance to compression is the characteristic that allows the transmission of applied forces in all hydraulic systems. At the same time, the ease with which gases and vapors may be compressed is the characteristic that makes them useful in various compressed gas systems.

The specific weight of a substance is the weight of that substance per unit volume. For most shipboard fluids, specific weight is expressed in pounds per cubic foot.

The specific volume of a substance is the volume that is occupied by a unit weight of the substance. For most shipboard fluids, the specific volume is expressed in cubic feet per pound.

The specific gravity of a substance is the ratio between the weight of that substance and the weight of a standard substance where both are measured under standard conditions of pressure and temperature. For solids and liquids, the standard substance used for comparison is pure water. Pure water has a specific gravity of 1. Therefore, a substance lighter than water will have a specific gravity that is less than 1. At the same time, a substance heavier than water will have a specific gravity that is greater than 1. Specific gravity is an important property for most petroleum products. As a rule, the specific gravity of petroleum products is expressed in degrees API, according to a scale established by the American Petroleum Institute using the hydrometer scale reading.

The viscosity of a fluid is a measure of its resistance to flow. A fluid has a high viscosity if it flows sluggishly. An example is cold molasses. A fluid that flows freely, like water, has a low viscosity. Gases and vapors have lower viscosities than liquids. The viscosity of liquids will vary a great deal. In general, fuel oils and lubricating oils have high viscosities. Raising the temperature of a fluid will lower the viscosity, while lowering the temperature will raise the viscosity.

The viscosity index of an oil is a number that indicates the effect of temperature changes on the oil's viscosity. An oil that becomes thin at a high temperature and thick at a low temperature has a low viscosity index. An oil that has relatively little change in viscosity with various changes in temperature has a high viscosity index.

The volatility of a liquid refers to the ease with which the liquid will vaporize or evaporate. If a liquid is both volatile and flammable, it must be handled with great care to prevent a fire or explosion. Gasoline is a good example of a liquid that is both volatile and flammable.

The operating conditions of a piping system are important because they have a definite effect on the fluid carried by the system. Pressure and temperature determine the physical state of a substance; that is, whether it is solid, liquid, or gas. Pressure and temperature also have definite effects on the specific weight, specific volume, viscosity, volatility, and other properties of the fluid.

The flashpoint of a liquid is the temperature at which the liquid gives off enough vapors to ignite momentarily, or flash, when a flame is applied. A hydraulic fluid with a high flashpoint is desirable because of its resistance to combustion and low degree of evaporation at normal temperatures.

The fire point of a liquid is the temperature at which a liquid gives off enough vapors to ignite and continue to bum when exposed to a spark or flame. A desirable hydraulic fluid requires a high tire point as well as a high flashpoint.

You will find more information on the characteristics of fluids in *Fluid Power,* NAVEDTRA 12964.

PIPING SYSTEM DESIGN

You should have some knowledge of the principles used to design and lay out piping systems. The information given in this chapter is general in nature. Detailed information can be found in contract specifications and in NAVSEA plans and drawings.

All shipboard piping systems have some corrosion caused by the fluids they carry, which act upon the metal of the pipe. You can minimize internal corrosion by using piping material that will resist the corroding effect of the fluid being carried. You can prevent external corrosion if you keep the outer surfaces dry and properly painted (except for brass and copper pipe).

The design, material, dimensional allowances, installation procedures, and safety codes for piping systems are governed by military standards and specifications. The following sections deal with some important aspects of piping system design.

PIPE SIZE

The size of pipe to be used in a system is based on the pressure drop as determined by the available pressure and the flow requirements of the system. The velocity used in the calculations usually is left to the judgment of the designer. However, special operating considerations may place limitations on the allowable velocity. For example, the velocity of seawater is restricted to a maximum of 15 feet per second to minimize the effect of erosion. Table 15-4 lists acceptable water velocities and flows used in piping system designs.

Table 15-4.—Volume Rate of Flow for Water (Not Feed)

NOMINAL PIPING SIZE *(inches)*	THICKNESS *(inches)*	INTERNAL DIAMETER *(inches)*	ALLOWABLE VELOCITIES *(feet per minute)*	VOLUME OF FLOW *(gallons per minute)*
314	0.065	0.920	210	7.26
1	0.065	1.185	270	15.47
1-1/4	0.065	1.530	343	32.76
1-112	0.065	1.770	403	51.51
2	0.065	2.245	500	102.82
2-1/2	0.072	2.73 1	592	178.48
3	0.083	3.334	685	3 10.66
3-1/2	0.095	3.810	753	445.97
4	0.109	4.282	803	600.72
5	0.134	5.295	860	983.52
6	0.156	6.313	887	1,442.16

The minimum thicknesses of pipe and tubing are determined by the stresses on the material. These stresses will vary with the difference in operating temperatures and pressures. A manufacturing tolerance is added to obtain a nominal wall thickness and to compensate for the decrease of the wall thickness caused by making bends in the pipe or tubing. Piping used to carry seawater will have an extra allowance added to compensate for corrosion. The various military specifications for piping and tubing will also include information on the wall thickness to be used for different applications.

DESIGN REQUIREMENTS

The requirements governing the design and arrangement of shipboard piping systems are covered in detail by contract specifications and by a number of NAVSHIPS plans and drawings. The information given here is not intended as a detailed listing, but merely as a general guide.

All shipboard piping systems must be installed so that they will not interfere with the operation of the ship's machinery or with the various doors, hatches, scuttles, manhole covers, or inspection plates. Also, the piping must not interfere with the maintenance or repairs of the machinery or ship's structure. If there is no way to prevent interference with other piping systems, machinery, or ship's structure, then the piping should be installed so that it can be removed easily for access to the material behind it. The location of cutoff valves, unions, and flanges must be carefully planned. These locations should isolate sections of piping with the least amount of interference to the operations of the rest of the system. Piping that is vital to the ship's propulsion system must not be installed where it would have to be dismantled to allow routine maintenance on machinery or on other systems.

When the type of cutout valve is not specified, select the one that is best suited for the service condition. Sometimes, the pressure drop or turbulent flow characteristics of globe and angle valves will be harmful to the components of the system. In these cases, a gate type is generally installed when no throttling will be required.

Avoid unnecessary high points and low points in piping systems. Where they are unavoidable, install vents, drains, or other devices to ensure proper functioning of the system and of the machinery and equipment served by the system.

Components welded in a piping system must be accessible for repair, reseating, and overhaul while in place. Complex assemblies such as valves, strainers, and traps in high-pressure drain systems must be removable as a group if they require frequent overhauling and cannot be repaired in place.

Valves should be designed so that they can be operated with a minimum amount of force and with maximum convenience. Sometimes you must stand on slippery deck plates to turn a valve handwheel, or you must reach over your head or around a comer. In these situations, you cannot apply the same amount of torque that you could if the handwheel was more conveniently located. Therefore, the location of the handwheels is a very important design consideration. (When possible, valves should be installed in the upright position.) Toggle mechanisms or other mechanical advantage devices must be used where the amount of torque required to turn a handwheel is more than could normally be applied by one person. Keep the mechanical advantage devices well lubricated. If they do not produce easy operation of the valve, then a power operation must be used.

Install locking devices if accidentally opening or closing a valve could endanger personnel or the ship. Any locking device installed on a valve must allow ease of operation and discourage unauthorized personnel from tampering with the valve.

Globe valves may be installed so that the pressure is applied either from the top or the bottom of the disk. The method used will depend on which one is best for operating, protecting, maintaining, and repairing the machinery served by the system. When a continuous flow is required and no harm will result if the disk of a globe valve becomes detached from the stem, the pressure should be below the disk. Where damage is likely to occur if the disk becomes detached from the stem and leaves the valve wide open, the pressure should be above the disk. Check valves must be installed so that the disk will open when the fluid flows in the correct direction, and close if back flow occurs in the line.

Flanged and union joints should be located where they are least affected by pipe line forces caused by thermal expansion or other causes.

Changes in direction of piping should be made by pipe bends and offsets where space permits. Otherwise, straight lengths of pipe and the fittings specified for the system should be used.

DESIGN RESTRICTIONS

Do not pierce decks and bulkheads unless it is absolutely necessary. This is particularly true of main subdivision bulkheads. When piercing is necessary, try to do it close to boundaries of compartments and avoid cutting bulkhead stiffeners, deck beams, and plating butts and seams.

Piping under pressure should be routed around voids, cofferdams, and other nonvented spaces. Bypass inner bottoms, ballast tanks, fuel tanks, freshwater trunks, and voids except when it is necessary to service these units.

Some piping systems other than those serving a tank are permitted to pass through fuel oil or diesel oil tanks. This piping must be of schedule 80 thickness if made of steel, and must have welded joints.

Combustible and flammable liquid piping is to be located at least 18 inches away from surfaces that have temperatures under their insulation greater than 450°F. This temperature limitation can be 650°F for surfaces in the vicinity of lubricating oil piping.

Do not install steam and liquid piping near electrical equipment if at all possible. Any drips or sprays from leaks along with condensation could damage the equipment. If the system has to be installed near electrical equipment, install adequate shielding to protect the equipment. Any flanges or unions in the system are to be installed away from the electrical equipment.

The amount of piping passing through messing and berthing spaces should be kept to a minimum. The piping in such spaces should be symmetrical, neatly arranged, inconspicuous, and should not interfere with the efficient functioning of the system.

Try to keep piping out of medical and dental spaces except where it is necessary to service the equipment in the space.

JOINTS AND CONNECTIONS

Welded joints are currently used whenever possible in carbon steel, alloy steel, and other weldable piping. These welded systems will have several types of valves with flanged connections to allow their removal for repairs. Some of the valves are throttle valves and valves that operate either automatically or semi-automatically, such as safety, relief, regulating, and governing valves. Use pipe bends to keep the number of joints down to a minimum.

EXPANSION JOINTS

Expansion joints must be kept in effective working condition. Indicators are often fitted on expansion joints to show whether or not the joint is functioning properly. Where such indicators are not fitted, a comparison of measurements taken on an expansion joint before and after the system has reached its operating temperature will indicate clearly whether or not the expansion joint is working properly.

Expansion joint bodies must be mounted securely so that the movement is confined only to the part that is supposed to move.

The expansion joint is absolutely necessary for high-temperature steam systems. Metal expands when heated and contracts when cooled. Steam lines are no exception. Unless steps are taken to allow for expansion and contraction, the tremendous stresses in the steam systems will cause failures.

Expansion joints used on board ship include slip joints and various corrugated and bellows-type joints.

Slip joints of the type shown in figure 15-28 are used for some low-pressure piping. A slip joint consists of a stuffing box, a packing gland, a male sliding tube, a female receptacle tube, and stop bolts that prevent separation of the male and female sections of the joint. The stuffing box and the male tube are flanged so that the assembly can be connected to the piping. The packing in the stuffing box is compressed by studs and nuts. The compression of the packing prevents leakage at the joint as the pipe moves in and out for a limited distance.

Slip-type expansion joints were once commonly used in shipboard steam piping systems. These joints are suitable only for low pressures, however, and the increasingly high steam pressures on naval ships has led to the use of other types of expansion joints in most steam systems. Slip-type expansion joints are still being used on many naval ships for steam escape piping systems.

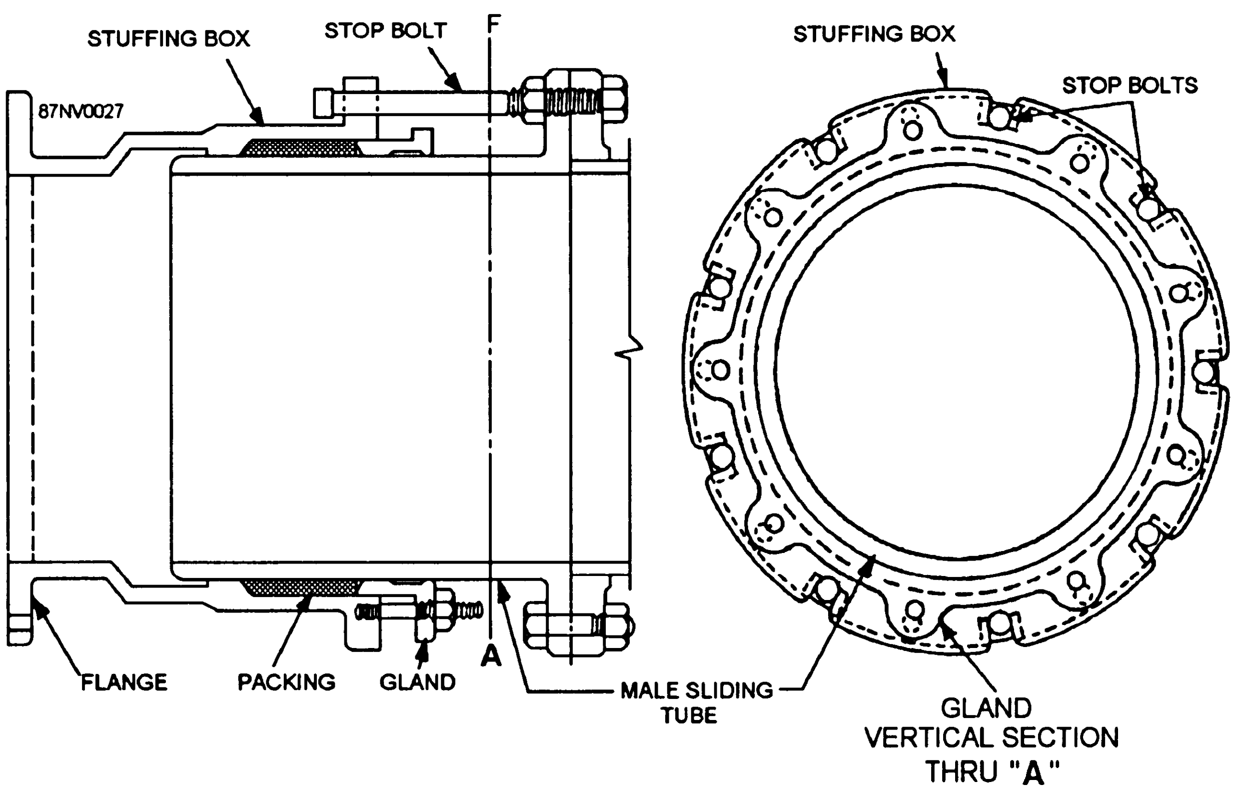
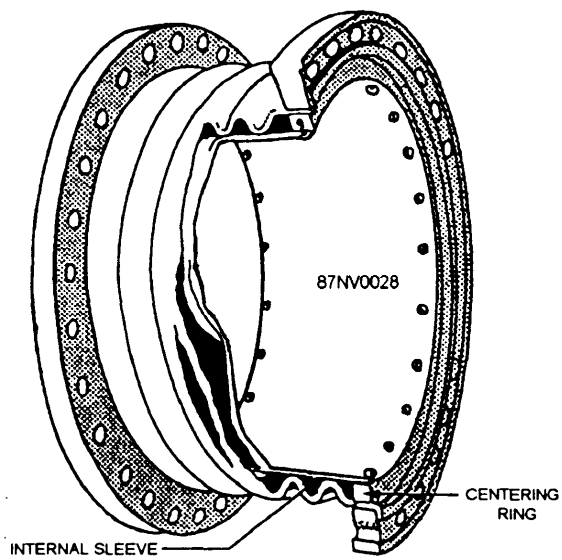


Figure 15-28.—Slip-type expansion joint.

Corrugated and bellows-type expansion joints (fig. 15-29) are used for both medium- and high-pressure piping systems aboard ship. These joints are used to allow both axial and radial movement of main steam piping where it passes through the bulkhead.

Corrugated and bellows-type expansion joints are made of various materials, including hard rubber, copper, nickel, and stainless steel. The accordion-like action of the corrugation or of the bellows allows the system to expand or contract. The movement of the pipe is absorbed by the changing curvature of the corrugations or of the bellows.



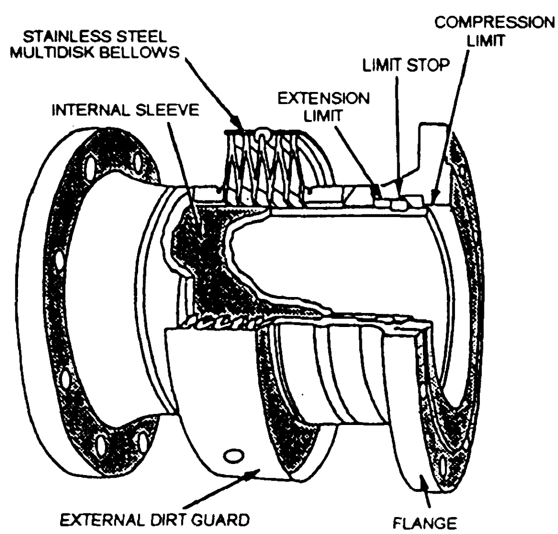


Figure 15-29.—Corrugated and bellows-type expansion joints.

EXPANSION BENDS

Loops, U-shaped bends, and offsets are fitted into piping systems so that the expansion or contraction will be absorbed by the bending in the pipe that forms the bend. Because expansion bends are more reliable and normally less expensive than expansion joints, they are preferred when conditions permit their use. Figure 15-30 shows a common type of expansion loop. Expansion bends and joints can be flexed in both directions from their normal position. They should be installed so that they are stressed in one direction when the piping is cold, and stressed in the other direction when the piping is hot. The amount and direction of the prestress or cold pull-up to be applied to piping and expansion bends or joints is indicated on the appropriate ship's plans. These instructions must be followed carefully to prevent failure of the expansion joints, piping, and connected equipment.

COLD SPRING JOINTS

Another method used to provide for expansion in high-pressure piping is the cold spring joint. The pipe for this joint is cut short an amount usually equal to one half the computed expansion. After the system is fabricated and ready for installation, a dutchman (an accurately machined blank flange), equal in thickness to the required amount of cold spring, is inserted between the flanges of the cold spring joint. When all other connections have been made, the dutchman is removed and the joint set up to about 40,000 psi with temporary pull-up bolts. The temporary bolts are then replaced one by one with permanent installation bolts set up to the required bolt stress.

WELDED AND BRAZED JOINTS

The majority of joints found in subassemblies of piping systems are welded joints, especially in high-pressure piping. The welding is done according to standard specifications that define the materials and

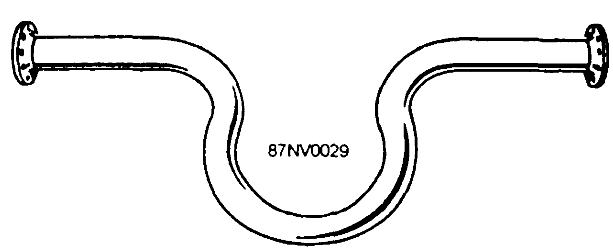


Figure 15-30.—Expansion loop.

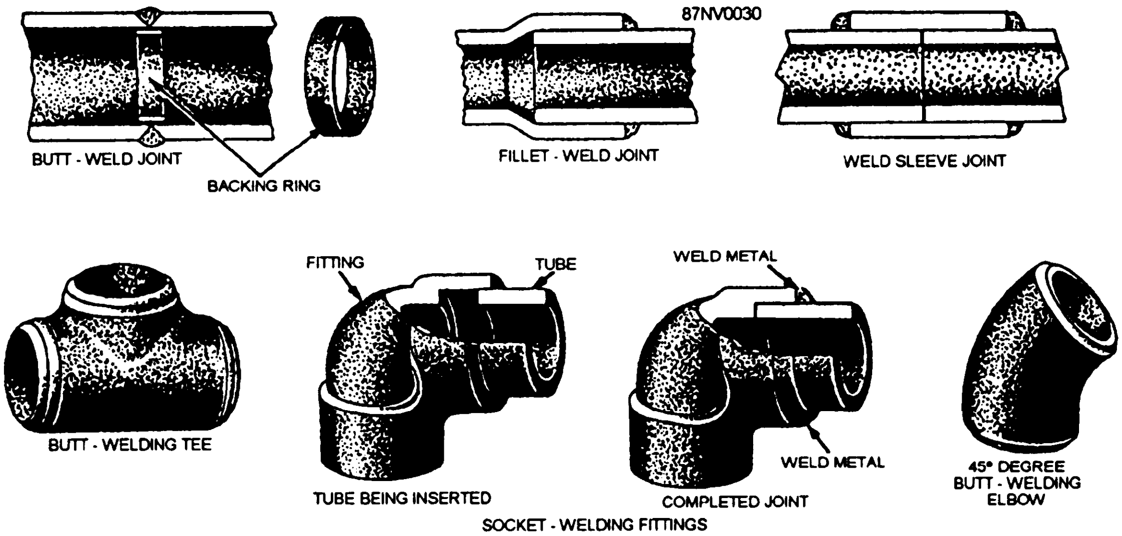


Figure 15-31.—Various types of welded joints.

techniques. There are three general classes of welded joints: butt-weld, fillet-weld, and socket-weld (fig. 15-31).

Welded joints normally permit welding from both sides. If not, backing rings should be used to ensure complete weld penetration.

Brazed joints must have sleeves or sockets. The fittings must have preinserted rings of silver brazing alloy. Also, the welded and brazed joints must meet the requirements established by MIL-STD 22. Examples of silver-brazed joints are shown in figure 15-32.

FLANGED JOINTS

Flanges are installed in piping systems to allow ready removal of piping. This provides for portability of machinery and equipment, access to equipment, and convenience for maintenance. The material and design of flanges are determined by service conditions.

PIPING STRESSES

The selection of piping material, size, and wall thickness was discussed earlier in this chapter. The type of service and flow rates determine material and size. Internal pressure determines wall thickness or strength of piping. If the strength is not to be exceeded, do not subject piping to any unusual stresses, such as would result from misalignment, vibration, improperly adjusted hangers, supporting chain falls, and so on.

THERMAL EXPANSION

All common piping materials will expand when heated and contract when cooled. If piping is confined

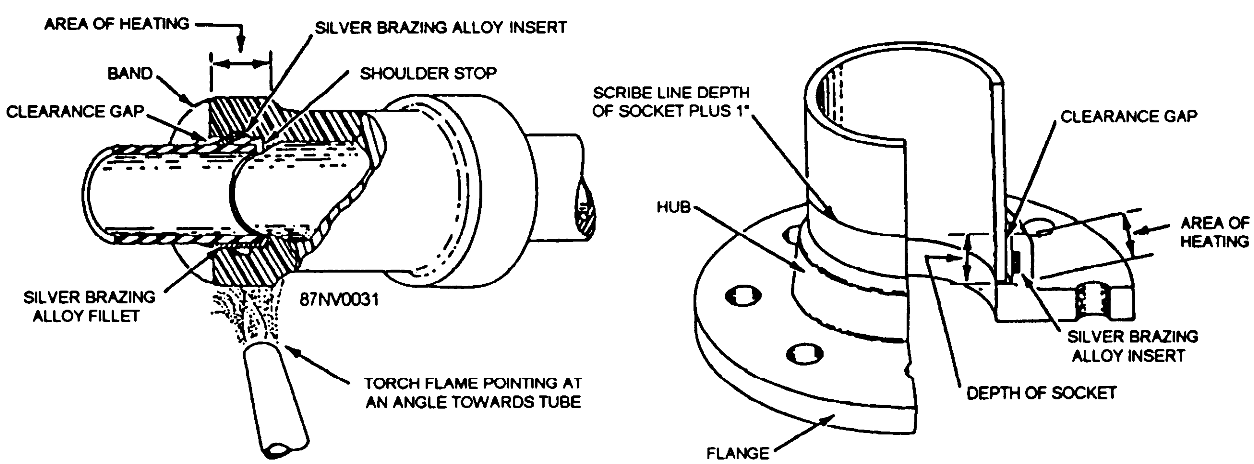


Figure 15-32.—Silver-brazed joints.

so this expansion and contraction cannot take place, large forces are generated. For example, a 40-foot long straight section of 6-inch, schedule 40, carbon-moly steel pipe will elongate about 3 inches when heated from ambient temperature to 454°C (850°F). If the pipe is confined so that expansion (or bending) cannot take place, a force of 870,000 pounds is generated within the piping material. As containment of a force of this magnitude is difficult, the procedure normally used is to allow the expansion or contraction to take place and absorb the motions in expansion bends or expansion joints.

PRESTRESS

Expansion bends and joints can be moved in both directions from their normal position. Install them so they are stressed in one direction when piping is cold, and in the other direction when piping is hot. The appropriate ship drawings indicate the amount and direction of this prestress or rold pullup to be applied to the piping and expansion bends or joints during installation in the cold condition. Carefully follow these instructions to prevent overstressing and possible failure of the expansion joints, piping, and connected equipment.

PIPE HANGERS, SUPPORTS, AND SWAY BRACES

Hangers and supports are used to describe the various devices used to carry the weight of piping systems. Although often used interchangeably and sometimes even together, the term *hanger* more correctly refers to a device that carries the piping weight from above, and the term *support* generally refers to a device that carries the piping weight from below. The term *support* is commonly used, in a broader sense and in this chapter, to include any device that carries the piping weight from above, from below, or even from the side.

Supports are generally arranged so that they carry an equal share of the piping weight so pipe stresses due to bending effects are minimized. When heavy load concentrations, such as vertical runs, valves, and strainers are present, additional supports are provided as close as practical to these items.

Design of supports are either of the rigid (solid) type or resilient type. Rigid types provide significant restraint in at least one direction. Resilient supports include one or more elastic members, such as springs or rubber elements, and are selected to permit limited pipe movements where movement is necessary to avoid overstress due to expansion or contraction of the piping. Rigid supports are generally used in cold piping systems. Cold systems in this context means systems where the fluid temperature does not exceed 120°F. One end is usually bolted or welded to a clamp on the pipe and the other end bolted or welded to the ship structure.

Similar alternate rigid-type designs using pipes and angles instead of flat bars are also commonly used. Since the flat bar is relatively weak in bending in one direction, it is often necessary to use supports incorporating either angles or pipe to provide the necessary rigidity to resist movement of the pipe that would occur due to ship motion or shock forces.

In hot piping systems, because of the movement of the piping due to thermal expansion, it is generally necessary to use resilient supports. In some locations where the pipe movement is small, it is sometimes possible to use rigid style supports. To balance the load between rigid style supports and resilient supports, it is necessary to make rigid types adjustable. Generally this is accomplished by using threaded rods or turnbuckles.

VARIABLE-SPRING PIPE SUPPORTS

Variable-spring supports are generally used in hot piping systems to carry the weight of the piping while allowing movement of the piping due to thermal expansion. The variable-spring pipe support consists of a heavy enclosed spring, generally attached to the pipe, using an adjustable rod and pipe clamp. The variable springs are marked by the manufacturer with hot and cold load indicator settings. The term *variable* comes from the characteristic of the unit that the force applied to the pipe is directly proportional to the movement of the pipe. The cold setting is calculated by the designer and it facilitates adjusting the spring support with the piping system cold. When the piping system is at its maximum operating temperature, the load indicator should be at the hot setting. Figure 15-33 indicates some applications and examples of this type of support.

CONSTANT SUPPORTS

Constant supports arc also used in hot piping systems and provide a constant supporting force for the piping throughout the expansion and contraction deflection cycle of the piping system. This is done by the use of a heavy encased spring working with a

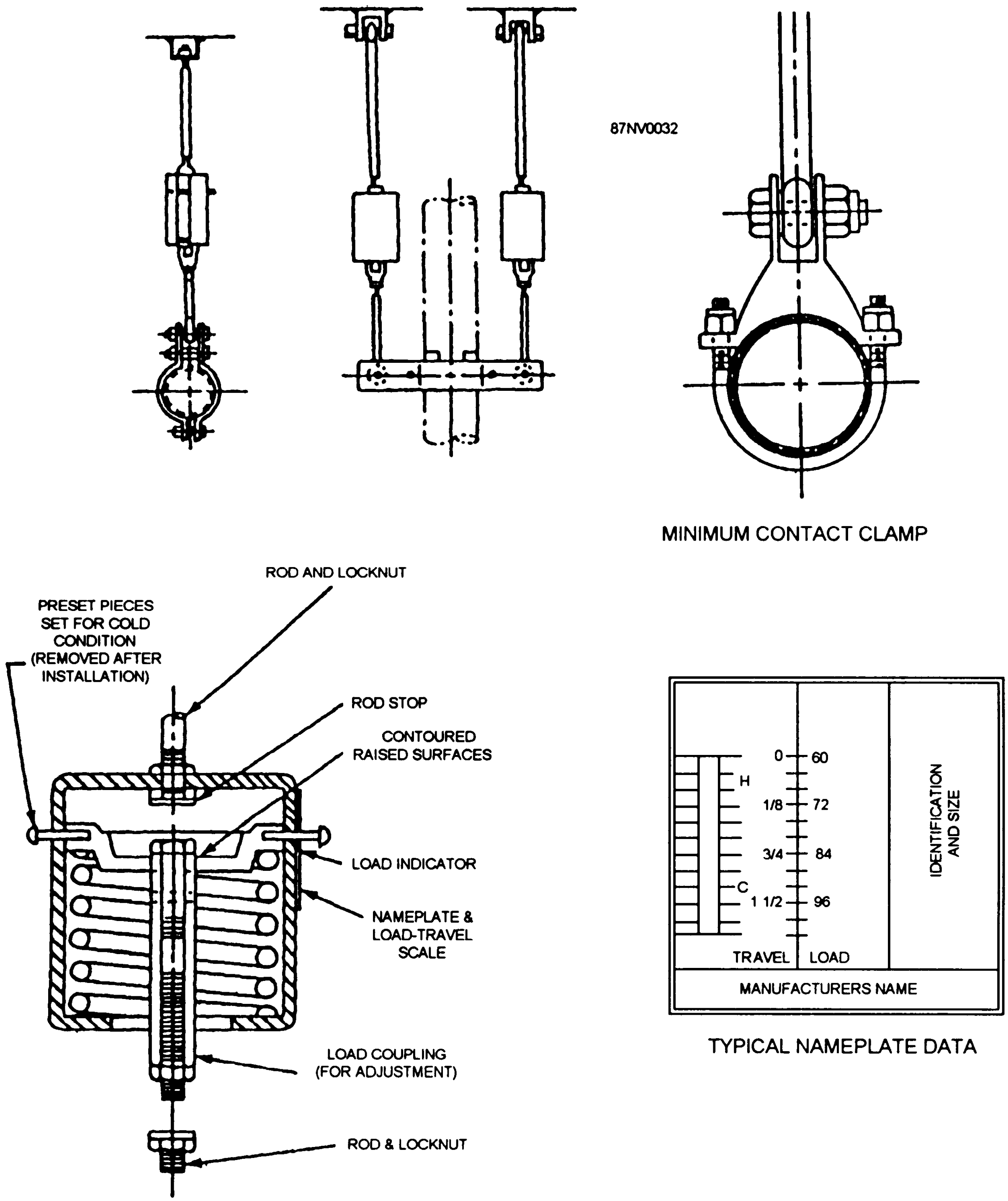


Figure 15-33.—Variable support pipe hangers.

mechanical bell crank lever. The frame portion of the hanger is secured to the ship's structure or foundation, whereas the lever is attached to the spring and to the pipe using an adjustable rod and pipe clamp. This support provides a constant force equal to the pipe weight regardless of the position of the pipe. Because these supports will allow pipe movement without varying the forces applied, they are used where pipe stresses are critical and where it is necessary to avoid transferring any load from the piping to equipment connections or other supports either in the hot or cold condition. Figure 15-34 shows some applications and examples of this type of support.

SWAY BRACES

To prevent swinging motions or vibration of piping or to resist shock or impact loads, anchors (rigid or sway braces, rigid and spring type) are normally installed. Anchors generally consist of structural members welded to the pipe and, in turn, to the ship structure such as a deck or bulkhead.

Sway braces are generally mounted horizontally and are not designed to support the weight of the piping system. Sway braces are adjusted so that no force acts on the pipe in the hot condition but will provide restraint

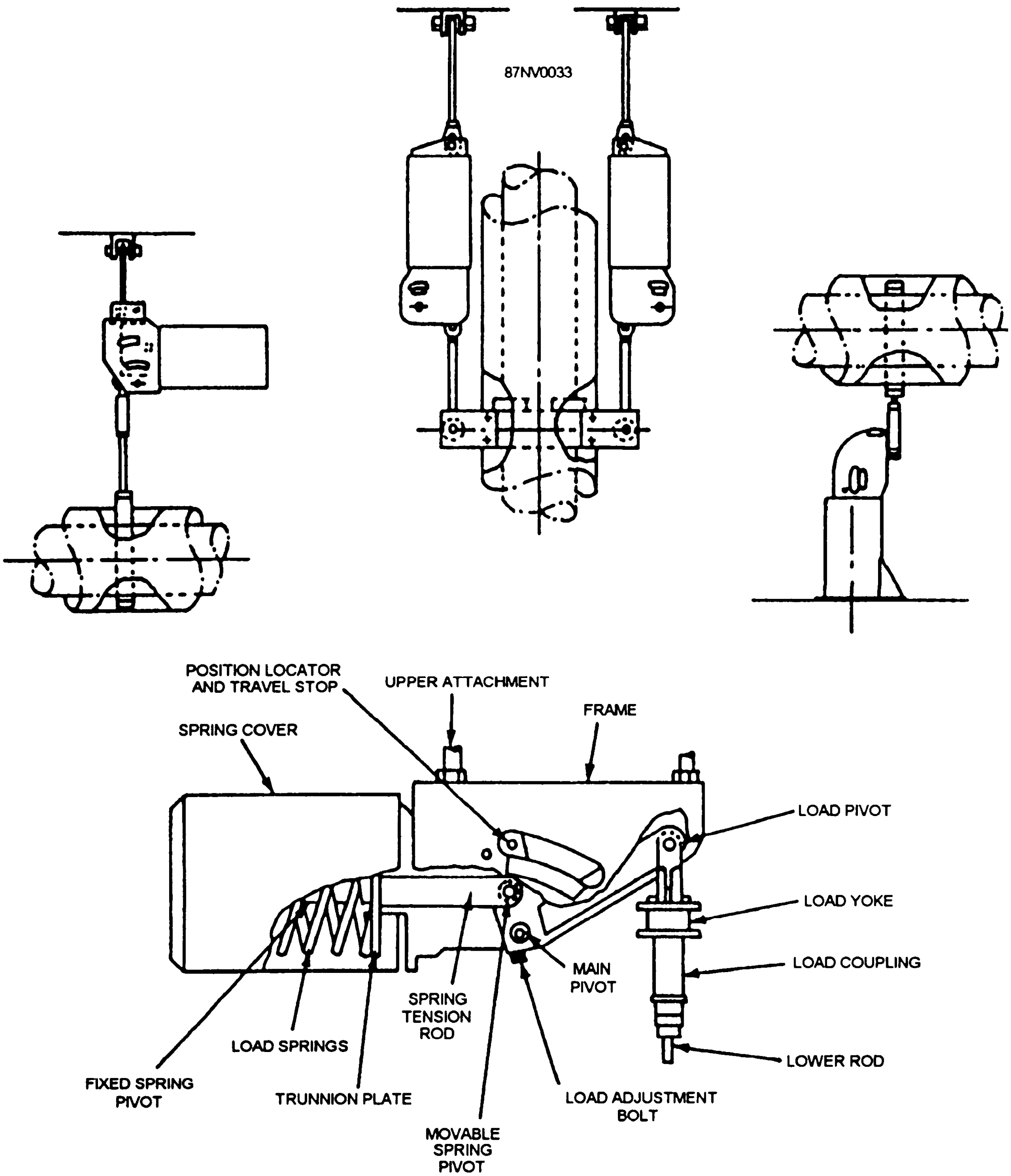


Figure 15-34.—Constant-support pipe hangers.

if any motion of the piping should occur along the axis of the sway brace. Figure 15-35 indicates some applications and examples of braces. As shown on the lower sketch, some old style sway braces are provided with tension test collars used to determine if the spring plates are against the end plates (neutral position) and whether there is clearance between the rod coupling and the spring plate. The tension test collar must be handtight when the piping system is hot, indicating the sway brace is in the desired neutral position.

SHIPBOARD PIPING SYSTEMS

As a Hull Maintenance Technician, you will be chiefly concerned with the maintenance and repair of the freshwater system, firemain system, flushing system, and low-pressure air piping. Therefore, you

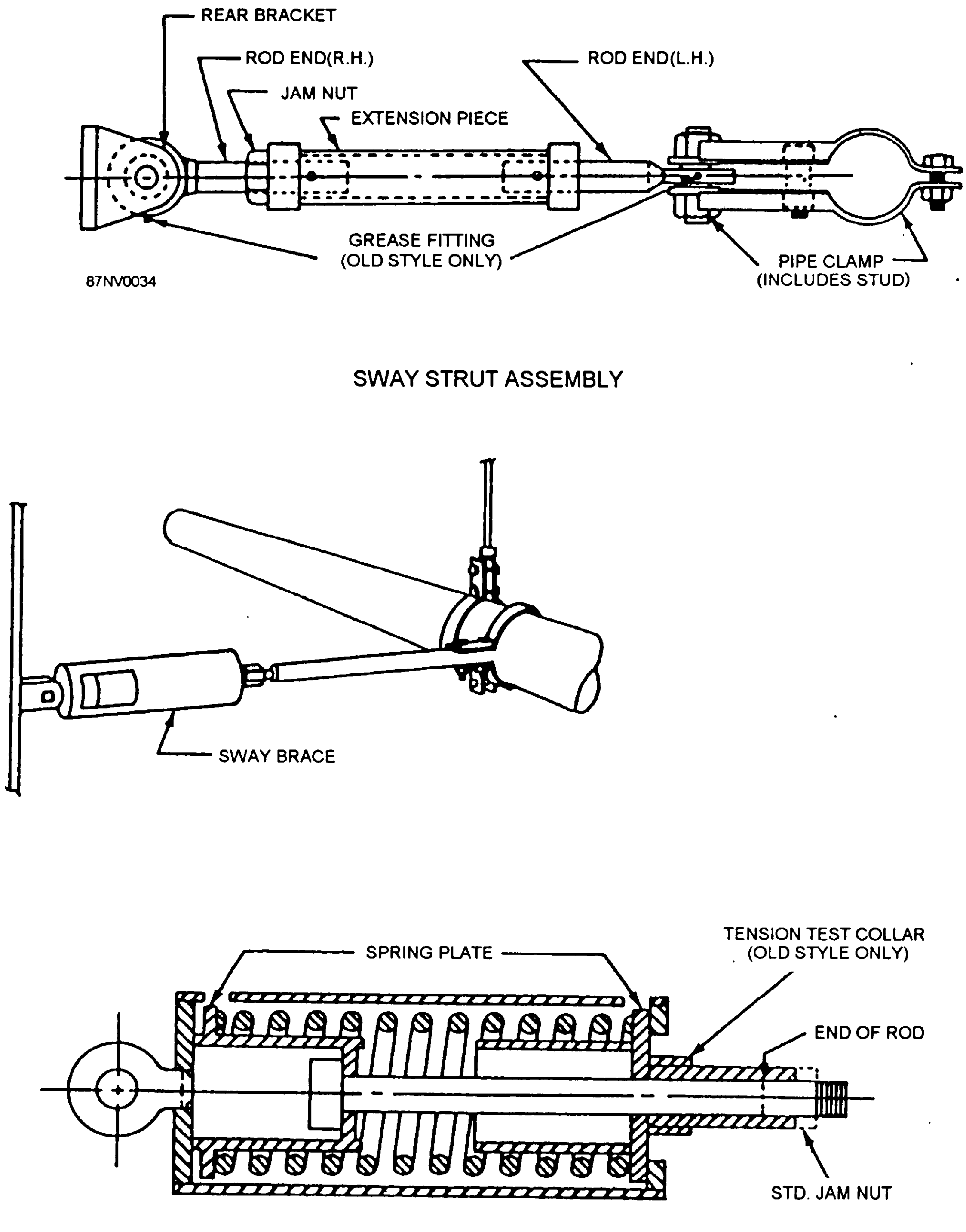


Figure 15-35.—Sway braces (single spring design).

should have a wide knowledge of shipboard piping systems.

Symbols make it easier to show piping systems on paper. These symbols represent the valves and other pieces of equipment. Figure 15-36 shows some of the symbols generally used in engineering plans and diagrams. There may be slight differences on some drawings; but, in general, the symbols will be like those illustrated. These symbols will help you to understand

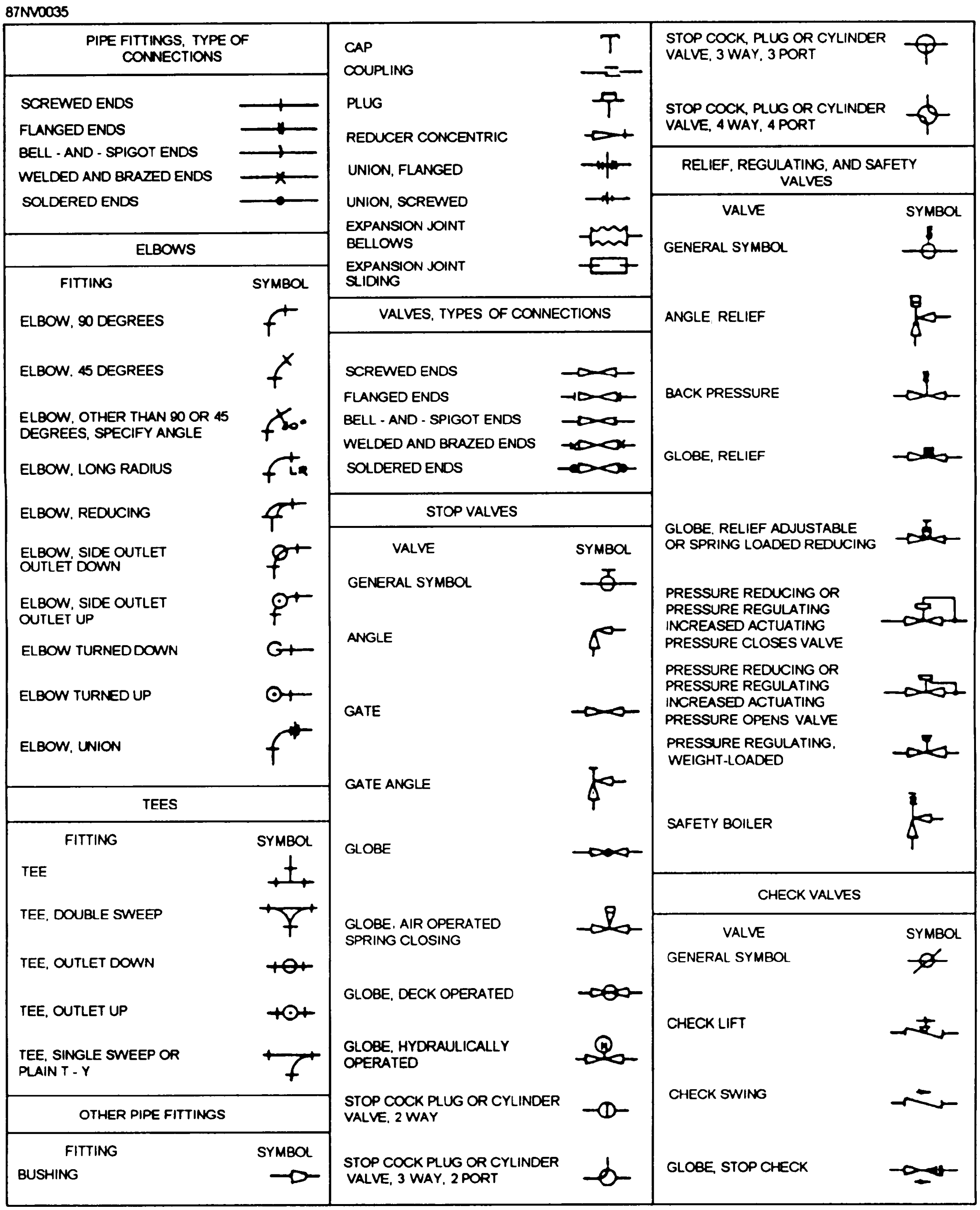


Figure 15-36.—Symbols used in engineering plans and diagrams.

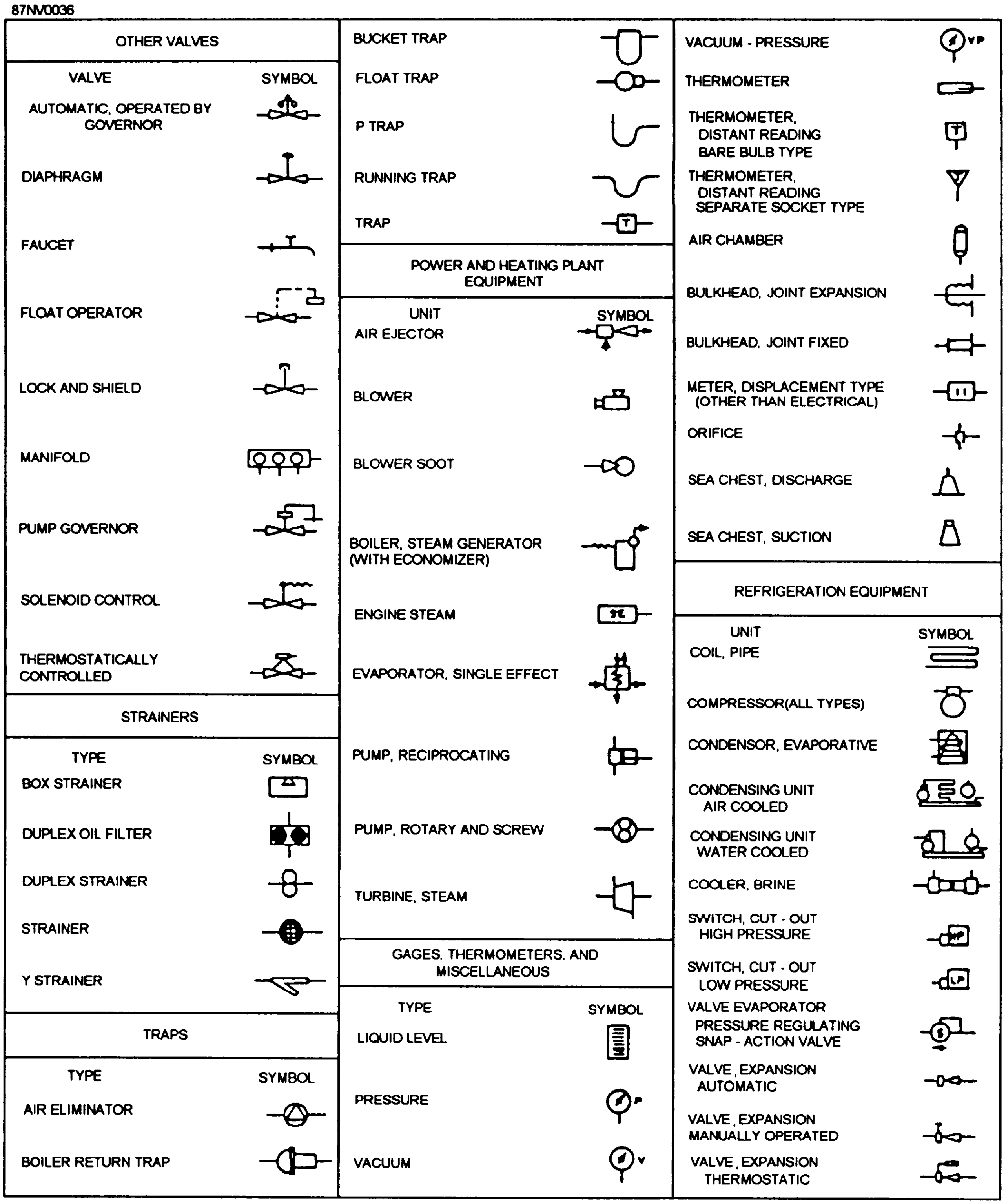


Figure 15-36.—Symbols used in engineering plans and diagrams—Continued.

the plans and diagrams you will study, and to draw your own rough sketches of the systems.

Remember that this chapter only gives general information on the various systems. Each ship is different, even sister ships. Therefore, to actually know your own ship's installation, you must check the details yourself.

STEAM SYSTEMS

Steam forms when water has been sufficiently heated. As heat is applied to a container partially filled with water, the temperature of the water rises until the boiling point is reached. At this temperature, small particles of water change to steam bubbles, which rise through the liquid to the surface and escape from the liquid. Although heat is continually being applied, the temperature of both the water and the steam remains constant at the boiling point until all water in the container has been converted to steam. About five times as much heat is needed to completely convert a given quantity of water to steam at the boiling point without an increase in temperature, as is needed to raise the temperature of the same quantity of water from 32°F to 212°F. The heat required to convert water at the boiling point to saturated steam at the same temperature is called latent heat.

There are two kinds of steam: saturated and superheated. Saturated steam is a vapor; superheated steam is generally considered a gas. As long as steam is in contact with water, it contains moisture in suspension. Steam in this condition and at the boiling point corresponding to its pressure is called saturated steam. Steam at the boiling point, but containing no suspended moisture, is called dry saturated steam. Saturated steam that has been heated to a temperature above the boiling point is called superheated steam.

Main Steam System

The main steam system is a comparatively short system but a very important one. Steam is generated in the boiler, then routed to the propulsion turbines, to the turbogenerators, and to the soot blowers via lines that are made of alloy steel piping. On older ships, flanged joints were used in the main steam system. On newer ships, welded joints are used whenever possible. The flanged takedown joints would be used only where the line goes to major units such as the turbines. The pressures and temperatures maintained in the main steam system are high. Some ships use pressures up to 600 psi and temperatures up to 850°F. Others go as high as 1200 psi and 975°F.

Auxiliary Steam Systems

Auxiliary steam systems are either high pressure or low pressure, depending upon the units that they serve. The high-pressure auxiliary steam system serves fire and bilge pumps, various service pumps, and fuel oil heaters. The piping and tubing is of the same material as that used in the main steam system.

The low-pressure auxiliary steam system is used for steam heat and for air ejectors in the distilling plant and main plant. Seamless steel, copper pipe, or copper tubing is used, and the fittings and flanges are either welded or silver-brazed. The auxiliary steam system is routed in the form of a loop, with cross connections at suitable intervals. Branch lines serve the various units of auxiliary machinery.

Auxiliary Exhaust System

The auxiliary exhaust system receives exhaust from all noncondensing steam-driven auxiliaries and uses this exhaust to supply the deaerating feed tanks (DFTs), the distilling units, and the turbine gland sealing system. The pressure in the auxiliary exhaust system is maintained at 15 psig. If the pressure goes above 15 psig, automatic unloading valves (dumping valves) allow the excess steam to go to either the main condenser or to the auxiliary condenser. If these unloading valves fail, relief valves allow the steam to escape to the atmosphere. If the pressure in the system drops too low, makeup steam is supplied from the auxiliary steam system through an augmenting valve.

Service Steam Systems

Service steam systems are low-pressure systems that serve compartment heating units, galley equipment, freshwater heaters, and laundry equipment. These are either constant service or intermittent service systems. Constant service steam systems are those in use the year around. Intermittent service steam systems are for heating services not required except in cold weather. Constant and intermittent service lines are usually cross-connected. Reducing valves in the branch lines leading from the 150-psi auxiliary steam system make it possible to reduce the steam to a suitable working pressure. Most service steam systems operate at 50 psi. The constant service system for laundry and tailor shop equipment operates at 100 psi.

WATER SYSTEMS

Generally speaking, there are two classes of water: fresh water and seawater. The term *fresh water* is used on board ship to refer to potable water, feedwater, reserve potable water, and reserve feedwater. Potable water is water known to be of drinking water quality. Feedwater is water known to be suitable for use in the ship's boilers.

The principal difference between fresh water and seawater is salinity. This difference leads to many other differences in characteristics. For example, under normal atmospheric pressure fresh water freezes at 32°F and boils at 212°F. Under the same pressure, seawater freezes at 27°F and boils at 213 1/2°F. Seawater and fresh water also differ in specific weight and in specific heat in Btu. (A Btu is the amount of heat required to raise 1 pound of a substance 1°F.) Fresh water is the standard of comparison for specific gravity and specific heat, and therefore has a specific gravity of 1 and a specific heat of 1. These factors will vary with the salinity of seawater. On the average, though, seawater weighs about 64 pounds per cubic foot (specific gravity varies from 1.0043 to 1.0463) compared with 62.4 pounds per cubic foot for pure fresh water. The specific heat of seawater varies from 0.903 to 0.980, depending on salinity.

The properties of water are influenced by temperature and pressure. For example, specific weight and viscosity of water change with temperature. The boiling and freezing points of water vary with pressure. At atmospheric pressure, fresh water boils at 212°F, but at an absolute pressure of 10 psi (equivalent to a vacuum of 9 l/2 inches of mercury) water boils at 193.1°F. At an absolute pressure of 30 psi, the boiling point is 250°F. At an absolute pressure of 900 psi, the boiling point is 531.9°F.

Water exists as a solid, a liquid, and a gas—that is, as ice at low temperatures and as steam at high temperatures. One of the peculiar characteristics of water is that it expands from 8.5 to 10 percent in volume when it freezes, and creates a pressure that would burst most piping and equipment. We have said that the specific weight of fresh water is 62.4 pounds per cubic foot. This is its maximum specific weight. At a temperature above or below 39.1°F, assuming 1 atmosphere pressure, the specific weight of fresh water is less than 62.4 pounds per cubic foot.

Condensate and Feed Systems

The condensate system and the boiler feed system, together, are usually known as the feedwater system. The condensate system includes all the apparatus and piping used to collect and condense steam. The condensate system includes the main and auxiliary condensers, a pump or a combination of pumps, and the piping required to carry the condensate from the condenser to the DFT. The main and auxiliary condensers recover feedwater by condensing exhaust steam from propulsion turbines, generator turbines, and various auxiliary machinery units.

The boiler feedwater system includes the DFT, the feed booster pump, the main feed pump, and the piping required to carry the feedwater from the DFT to the boilers. A small amount of additional water, called makeup feed, is usually required to make up for any loss that occurs in the cycle. This makeup feed is taken from the reserve feedwater tanks. All lines that carry water to the boilers, either from DFTs or the reserve feed tanks, are part of the feedwater system.

Steam and Freshwater Drains

Most of the feedwater in a shipboard steam plant is recovered so that it can be used over and over again for the generation of steam. As steam is condensed in the main and auxiliary condensers, the condensate is returned to the feed system. Also, the steam exhausted from auxiliary machinery is collected in the auxiliary exhaust system and is returned to the feed system. But steam is used throughout the ship in a good deal of machinery, equipment, and piping that does not exhaust either to a condenser or to the auxiliary exhaust system. Therefore, steam and freshwater drain systems are provided so that water can be recovered and put back into the feed system after it has been used (as steam) in fuel oil heaters, distilling plants, steam catapult systems, water heaters, whistles and sirens, and many other units and systems throughout the ship. The systems of piping that carry the water to the feed systems, and also the water carried in the systems, are known as drains.

There are four steam and freshwater drain systems on ships built to Navy specifications: (1) high-pressure steam drainage systems, (2) service steam drainage systems, (3) freshwater drain collecting systems, and (4) contaminated drainage systems. Most drain lines are fitted with steam traps to keep steam from passing into the drain systems. High-pressure drains are generally a mixture of steam and water, even after they have passed through steam traps. All of the other drains are in the form of water after they have passed through steam traps.

HIGH-PRESSURE STEAM DRAINAGE SYSTEM.—High-pressure drains generally include drains from superheater headers, throttle valves, main and auxiliary steam lines, steam catapults (on carriers), and other steam equipment or systems that operate at 150 psi or above. High-pressure drains are returned to the feed system by way of the DFT.

SERVICE STEAM DRAINAGE SYSTEM.—The service steam drainage system collects drains from low-pressure (below 150 psi) steam piping systems and steam equipment outside of the machinery spaces. Space heaters and equipment used in the laundry, the tailor shop, the galley, and the pantry are typical sources of drains for the service steam drainage system. On some ships, these drains discharge into the most convenient freshwater drain collecting tank. On other ships, particularly on large combatant ships such as carriers, the service steam drains discharge to two special steam drain collecting tanks located in the machinery spaces. One is in a forward machinery space, while the other one is in an after machinery space. The drains are then returned from the service steam drain collecting tanks to the feed system.

Note that the service steam drainage system collects only clean drains that are suitable for use as boiler feed. Contaminated service steam drains (such as those from laundry presses) are discharged as authorized.

FRESHWATER DRAIN COLLECTING SYSTEM.—The freshwater drain collecting system (sometimes called the low-pressure drain system) collects drainage from various piping systems, machinery, and equipment that operate at steam pressures of less than 150 psi. As we have seen, both the service steam drainage system and the oil heating drainage system can discharge to the freshwater drain collecting tank. However, they normally discharge more directly to the condensate of the feed system. In general, the freshwater drain collecting system collects gravity drains, turbine gland seal drains, auxiliary exhaust drains, air ejector condenser drains, and a variety of other low-pressure drains that result from the condensation of steam during warming up or operating machinery and piping. Freshwater drains are collected in freshwater drain collecting tanks that are located in the machinery spaces. The contents of these tanks are discharged to the feed system.

CONTAMINATED DRAINAGE SYSTEM.—A contaminated drainage system is installed in each main and auxiliary machinery space where dry bilges must be maintained. The contaminated drainage system collects oil and water from machinery and piping that normally have some leakage, and drainage from any other services that may at times be contaminated. The contaminated drains are collected in a bilge sump tank located in the same machinery space. The contents of the bilge sump tank do not go to the feed system; instead, they are removed by the bilge drainage system.

On recently constructed ships, drains that contain contamination are collected by separate waste water and oily water drain systems. Separating the drains permits discharging waste water drainage as authorized.

Freshwater Systems

Practically all fresh water used aboard ship is made by boiling seawater in the evaporators and condensing the resulting vapor. Fresh potable water is stored in potable water tanks at a distance from the machinery spaces. The water intended for boiler use is stored in feed tanks located in the double bottoms or in wing tanks adjacent to the machinery spaces. The potable water system supplies hot and cold potable water to scuttlebutts, sinks, showers, scullery, sick bay, and the galley. The normal operating pressure is approximately 35 psi. In some ships, water pressure is maintained by automatic electric pumps that take suction on the ship's potable water storage tanks. Constant pressure is maintained by admitting compressed air to the pressure tank. When there is a decline in tank pressure, the pump starts automatically. In some systems, the potable water pumps discharge directly to the distribution system. The pressure in the system is provided by the continuous operation of a motor-driven centrifugal water pump taking suction from the ship's tanks. When potable water is supplied to other systems, the supply to the nonpotable system is through an air gap. There should not be any direct cross connection between the potable water system and any other system. An air gap in a water supply system is the unobstructed vertical distance through free atmosphere between the lowest opening from any pipe or faucet supplying water to a tank or plumbing fixture and the flood-level rim of the tank or plumbing fixture. Each hose connection in the potable water system should be provided with a vacuum breaker backflow preventer on the downstream side of the hose control valve.

Some ships use instantaneous coil-type heaters in the hot water system. Other ships are of the circulating type, in which a circulator forces the water to move continuously through the system. This allows hot water to be available at the taps at all times and prevents the waste of potable water. The water is heated in a hot water tank by low-pressure auxiliary steam coils. This system will be secured during battle conditions when each battle dressing station is served by a separate storage tank and a small hot water heater. The water is routed from the tank to the electric water heaters at the stations.

Electronics Cooling Water System

Cooling water systems are now provided on most ships to cool electronics equipment. In this system, fresh water is usually circulated through the electronics equipment to carry away the heat generated during operation. Potable water taken on from shore should not be used to replenish the system. Only distilled water (0.065 equivalents per million (epm) chlorides maximum) should be used for replenishment. Where demineralizers are installed, electronics equipment should not be operated until the water conductivity is at or below the prescribed limit. For specific information on the system, the ship's information book or other sources of ship information should be consulted.

Firemain System

In ships built to Navy specifications, the firemain material must be made of copper-nickel alloy with copper-nickel or bronze fittings and bronze valves. There are, however, a number of older ships with firemain systems made of ferrous materials.

The pumps used to maintain pressure in the firemain system may be steam-driven reciprocating pumps or centrifugal pumps driven by steam turbines, electric motors, or (in some cases) diesel engines. These pumps are classified according to their use as tire pumps; fire and bilge pumps; fire and flushing pumps; or fire, flushing, and drainage pumps. Firemain working pressures vary from 50 psi on small craft to 175 psi on recently built ships.

You must be thoroughly familiar with the location of the firemain, the pumps, the riser piping, the fireplugs, the cross connections, and the principal isolation valves. Study the system aboard your ship by tracing the piping from bow to stern, from deck to deck, compartment by compartment. Then study the blueprints and diagrams of the system, and the information given in the Engineering Casualty Control Book, the Damage Control Book, and the General Information Book for your own ship.

Sprinkling Systems

Sprinkling systems are installed aboard ship in magazine turrets, turret handling rooms, hangar decks, missile spaces, and other spaces where flammable materials are stowed. Water for these systems is supplied from the firemain through branch lines. A gate valve is installed in each branch line, as close to the firemain as practicable, and ahead of the sprinkling control valves. The gate valve is normally kept in the open position by a securing device (NOT a padlock).

Most sprinkling systems aboard ship are of the dry type, that is, they are not charged with water beyond the sprinkling control valves except when they are in use.

Some missile magazines are equipped with a wet type of sprinkling system. These systems are charged with water up to the spray head valves. The sprinkling control valves in some systems are operated automatically, by heat-actuated devices. Others are operated manually or hydraulically, either locally or from remote stations. Figure 15-37 shows a hydraulic oil-operated control system for operating magazine sprinkling control valves. On more recent ships, the sprinkling control valves are actuated by a hydraulic saltwater control system supplied by the firemain system.

In the space being protected, the piping, fitted with spray nozzles, is installed in such a manner that no portion of the installation will form an obstruction to handling or stowing material in the space. On older ships, the piping does not have spray nozzles. Instead, holes are drilled in the upper portion of the distribution piping to permit water to spray on the overhead and bulkheads.

Most piping material used in sprinkling systems is copper-nickel. An exception is the piping grid in dry systems, which is made of aluminum alloy. The operating pressure is the same as that of the firemain.

For more complete details of sprinkling systems, consult your ship's General Information Book and Damage Control Book.

Water Washdown Systems

Water washdown systems are essentially dry pipe sprinkler systems. They have specially designed nozzles that are installed so that they will throw a large spray pattern of water. These systems are installed

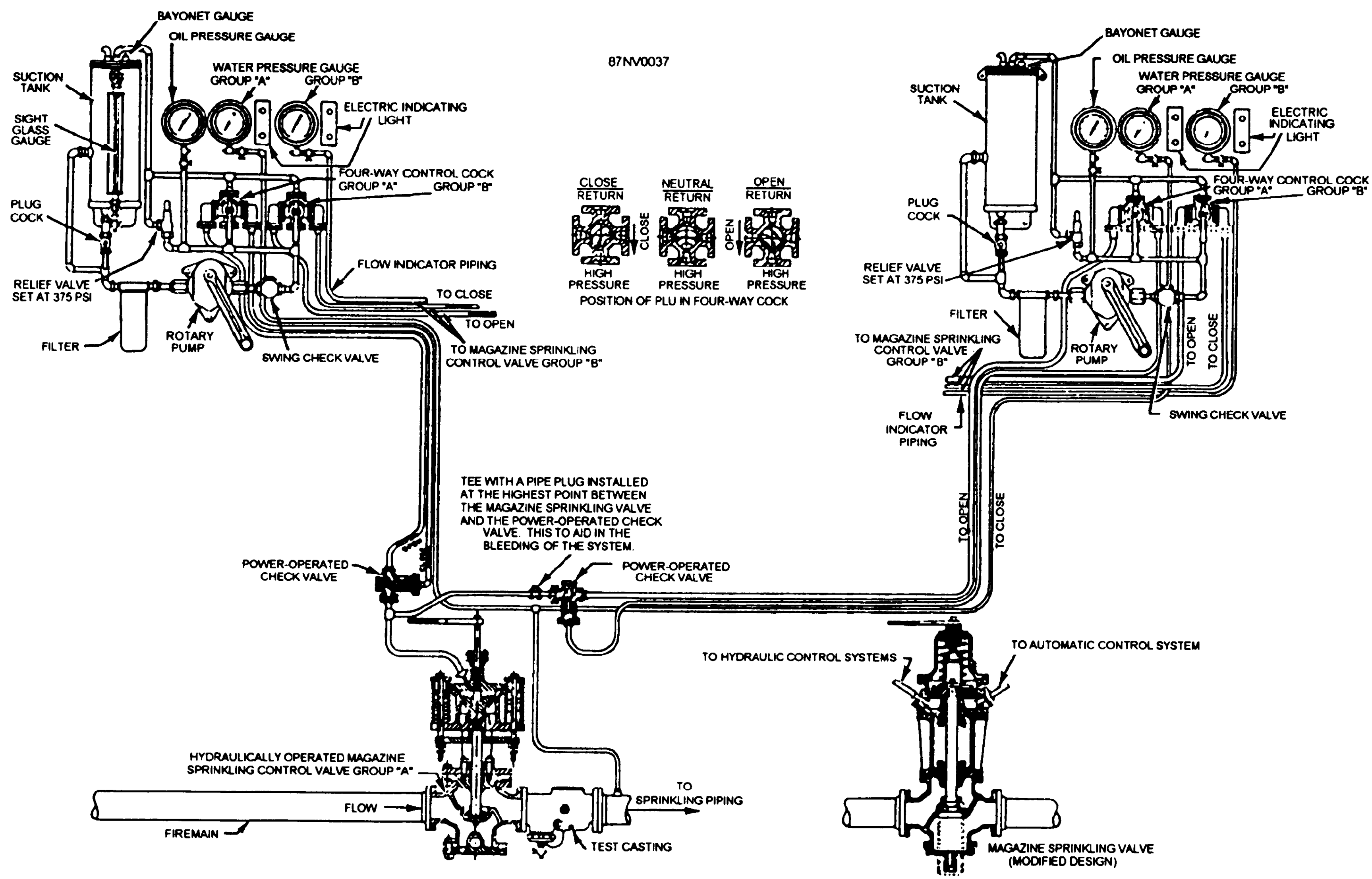


Figure 15-37.—Hydraulic control system for operating magazine sprinkling control valves.

aboard ship to provide a film of flowing water over all of the exterior surfaces of the ship. This flowing film of water prohibits chemical, biological, and radiological (CBR) agents or particles from adhering to the ship's exterior surfaces. For maximum effectiveness, the water washdown system should be activated before a CBR attack.

A permanent washdown system is now installed on any ship under construction or when it enters a shipyard for conversion. If a ship already in service does not have a washdown system, it will receive a kit to be installed by the ship's force as an interim measure. Both types are supplied from the firemain.

The interim water washdown system consists of a number of separate arrays (or pipe lines) connected to topside fireplugs by short sections of firehose, as shown in figure 15-38. Thus, the water washdown system, instead of being a continuous topside piping system, is rather a series of small piping arrays with each array supplied by its individual fireplug.

Each array consists of a series of plastic or aluminum pipes connected together and secured to topside structures. Each array is fitted with appropriately spaced nozzles, and the array and nozzles are arranged to ensure an effective coverage of weather decks by the water washdown spray. In general, each

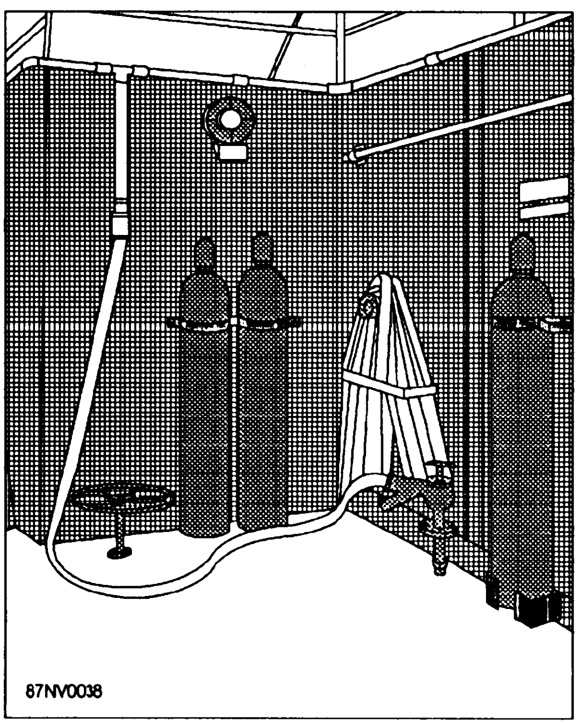


Figure 15-38.—Interim washdown system array connected to a topside fireplug.

fireplug supplies the washdown nozzle array in its immediate vicinity. A 1 l/2-inch fireplug can supply an eight-nozzle array and a 2 l/2-inch fireplug can supply a maximum of 22 nozzles.

In addition to the installed sections of the interim water washdown system, portable manifolds with spaced nozzles are provided to cover areas where fixed installations would be difficult to install or would interfere with normal operations. When not in use, they should be stowed as near their point of use as possible. Figure 15-39 shows a portable manifold stowed while not in use.

In FY-84, the improved water washdown system nozzles of LHSs and DD-963 class destroyers were replaced with NATO nozzles.

Flushing System

The flushing system for commodes and urinals is supplied with seawater either by a branch from the firemain or by a separate sanitary and flushing pump taking suction from the sea. When this system is supplied from the firemain, the branch is taken as near the top portion of the main as possible so that sediment from the firemain will not enter the flushing system. Since the firemain pressure is too high for a flushing system, the water is led through a strainer to a reducing valve, which reduces the pressure to 35 psi.

Air chambers are installed in the flushing system where it runs to urinals and water closets. These air chambers absorb water hammer caused by the quick closing of the flush valves and spring-closing faucets. If it were not for this provision, water hammer might rupture pipes, break joints, and damage valves.

Drainage System

The drainage system aboard ship is divided into two categories: the main and secondary systems, and the plumbing and deck drains. Between them, these systems collect and dispose of all the shipboard waste fluids as authorized. The main drainage system consists of piping installed low in the ship, with suction branches to spaces to be drained and direct connections to eductors or drainage pumps. This system generally serves the main machinery spaces and a few other spaces.

The secondary drainage systems supplement the main drainage system wherever the main system cannot be extended through spaces where piping is prohibited, or because the length of piping would be too great for

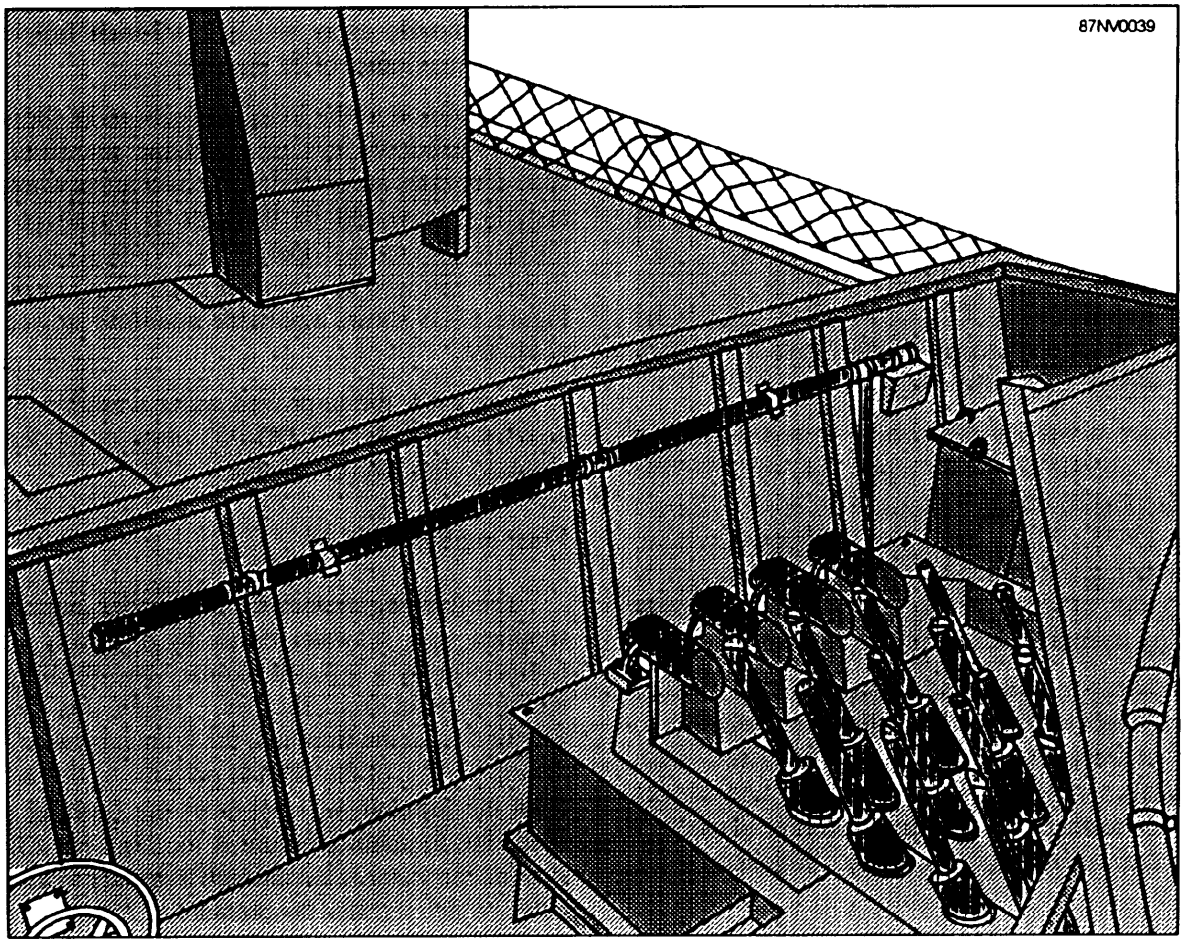


Figure 15-39.—Stowage of portable manifold for interim washdown system.

efficient drainage. Each secondary drainage system is independent of the main drainage system and has its own pumps or eductors and its own disposal connections.

Plumbing and deck drains are classified according to their type; either as soil or sanitary waste drainage. Drains from water closets, urinals, and similar fixtures flushed with seawater are soil drams. Most of the other plumbing drains are waste drams.

Since shipboard flushing systems use salt water, the soil drainage piping is usually of a copper-nickel alloy. This prevents the rapid deterioration caused by the corrosive effect of the salt water. The joints in copper-nickel piping are silver-brazed. The sanitary waste drains are usually made up of brass or copper.

All plumbing drainage systems must be vented. A vent line prevents the siphonage of traps and allows sewer gas to escape. As long as a system is properly vented, the air required for drainage is taken in through the vent line instead of through the drain receptacle of the fixture, and proper drainage of the trap will result.

FUEL OIL SYSTEMS

Naval ships now use a fuel oil known as fuel, naval distillate as their primary fuel. This fuel oil meets the requirements of specification MIL-F-16884. Other NATO countries have similar, if not identical, naval shipboard fuel specifications. Therefore, the NATO code number F-76 was assigned to the fuel, naval distillate.

The use of F-76 has increased the amount of time between fireside cleanings. Cleaning can be extended from one overhaul to the next, with periodic inspections held during the operational period. Fireroom maintenance and topside maintenance is reduced, while the reliability of the equipment has increased.

Therefore, the amount of time that the ships are available for operations has been increased significantly.

For the latest information concerning F-76, characteristics, handling, and testing, consult current technical manuals, instructions, directives, and notices, along with *NSTM*, chapter 541.

All fuel oil comes from petroleum. Crude petroleum consists of a number of different hydrocarbons-that is, compounds of hydrogen and carbon. Crude petroleum quite often contains traces of sulfur, nitrogen, oxygen, and other impurities.

Fuel oil itself is nonexplosive, difficult to ignite in bulk, and not capable of spontaneous combustion. Its vapors, however, form an explosive mixture with the oxygen in the atmosphere. The vapor is heavier than air and tends to collect in bilges and tank bottoms. Fuel oil vapor is always present in partially filed tanks or empty tanks from which the vapor has not been removed. Since this vapor is highly flammable, safety precautions must be continuously observed to prevent a fire or explosion.

The fuel oil system is arranged to allow the transfer of fuel oil from fueling connections to storage tanks, from storage tanks to service tanks, and from service tanks to the burners at the boiler. It also allows the transfer of fuel oil from one storage tank to another. These transfers are made with pumps, manifolds, and sometimes sluice valves, which permit gravity flow from one storage tank to another.

The filling and transfer system usually consists of two large lines, one on each side of the ship, running forward and aft. Cross-connections join these mains to the fuel oil booster and transfer pumps. Risers are provided fore and aft for taking on or delivering fuel.

The fuel oil service system consists of a service main, manifolds, fuel oil service pumps, meters, heaters, strainers, burner manifolds, the burner lines, and the burners at the boiler fronts.

LUBRICATING OIL SYSTEMS

The lubricating oil system supplies clean, cool oil to machinery bearing surfaces. Lube oil is routed from the filling connection to the storage or sump tank located within the engine room. From this tank it is pumped through a series of strainers and coolers to the bearing surfaces. Used oil is routed to a settling tank, then through purifiers, and back to the sump tank. The pressures to be carried at the various parts of the lubricating system differ with the type of installation.

HYDRAULIC SYSTEMS

Hydraulic systems work on the principle that liquids are noncompressible. Therefore, pressure or force exerted at any point on an enclosed liquid is transmitted equally in all directions. Hydraulic systems operate remote control valves for flooding, counter-flooding, and ballasting. Other examples of the transmission of power aboard ship by hydraulics are the operation of the steering gear, small hydraulic presses in the shop, and hydraulically operated pipe benders. The design and arrangement of the cylinders, pistons, pumps, reservoir fluid tanks, and piping that make up a hydraulic system permit a great deal of work with little effort on the part of shipboard personnel.

A satisfactory liquid for a particular hydraulic installation must have chemical stability, freedom from acidity, lubricating power, rust inhibiting qualities, a high flash point, a pour point well below minimum operating temperature, and a high viscosity index. If a hydraulic fluid did not possess chemical stability, operating the system for considerable periods at high temperatures would result in the formation of sludges, gums, and carbon deposits. These deposits, in turn, would clog openings, cause valves and pistons to stick or leak, and give poor lubrication to the moving parts. In petroleum-based fluids, chemical stability is improved by the use of chemicals called additives or inhibitors. Such chemicals are also used to attain freedom from acidity, improve lubricating power, improve the viscosity index, and lower the pour point.

A satisfactory fluid for a given hydraulic system must have enough body to give a good seat at pumps, valves, and pistons; but must not be so thick that it offers excessive resistance to flow. In other words, the viscosity of the fluid must be suitable for the system in question.

The medium used to transmit and distribute forces in hydraulic systems may be a petroleum-base product (hydraulic oil) or the recently approved pure phosphate ester fluid. Phosphate ester fluid is more fire resistant and explosion resistant than the petroleum-base oil used exclusively in hydraulic systems for many years. Phosphate ester fluid is now used in aircraft carrier elevators, surface ship missile systems, jet blast deflectors, seaplane servicing booms, high-pressure submarine systems, and for all new construction and conversion surface ships in which the hydraulic systems operate at pressures above 500 psi. Hydraulic systems may operate at pressures as high as 3000 psi. Those with maximum design pressures in excess of 300 psi may be fabricated from stainless steel tubing or from the copper or steel used for lower pressure systems.

GASOLINE SYSTEMS

Gasoline is a highly volatile mixture of liquid hydrocarbons. It is used as a fuel for internal combustion engines in aircraft, automotive equipment, and various other applications. Gasoline vapor, when combined with air in the proper proportions, forms an explosive mixture which can be set off by a slight spark or flame. Gasoline vapor is heavier than air. Therefore, it tends to collect at the bottom of storage spaces or it may travel along an air current a considerable distance. If the vapor is then ignited, it flashes back to the source, causing an explosion. If liquid gasoline is present along with the vapor, the explosion is followed by fire. The volatility of gasoline is demonstrated by the fact that one quart of uncovered gasoline upon complete evaporation will mix with 520 cubic feet of air to form an explosive mixture. This amount of air is normally contained in a space 10 by 6 l/2 by 8 feet. Air can absorb 28 percent gasoline vapor at normal atmospheric pressure. However, an explosive mixture exists only when the percentage of gasoline vapor in the air is between 1.4 and 2.5 percent.

Remember that gasoline is not only a potential source of an explosive mixture, but is also a toxic hazard. Keep it away from your skin, and do not inhale the vapors. Do not smoke or use naked lights in the vicinity of gasoline.

Remember also that a leaktight gasoline piping system is essential to the safety of your ship. To ensure that gasoline piping systems are leaktight, inspect all joints and valves frequently. Always use nonsparking tools when you are repairing gasoline piping systems.

Some ships have a gasoline system designed to prevent explosions resulting from the ignition of gasoline vapor during the fueling of aircraft and small boats. This system may be either an inert-gas blanket system or a saltwater displacement system. In the first type, inert gas is admitted to the storage tank and forms a blanket over the gasoline, thus preventing the formation of an explosive vapor. In the second type, the storage tank is first filled with salt water so that all air is excluded. Then gasoline is pumped into the tank, forcing a corresponding amount of salt water out at the bottom and into a gravity tank. As gasoline is pumped from the tank, salt water reenters from the gravity tank or from some other source of salt water supply. The storage tank is thus kept completely filled at all times, preventing the formation of gasoline vapor.

Some ships are provided with a specially constructed inert-gas piping system for lines running inside the ship. A double-pipe gasoline line is formed by running brass piping inside a steel tube, and filling the space between with an inert gas. The brass piping carries the gasoline. The free passage of the inert gas throughout the system is ensured by installing bypass tubes at each joint.

COMPRESSED AIR SYSTEMS

Air is a mixture (not a chemical combination) of several gases. The most important of these are nitrogen and oxygen, with small amounts of argon and neon.

Compressed air is neither poisonous nor flammable, but it should be handled carefully. Air tanks, lines, and fittings can rupture from too much pressure. Carelessness with compressed air can also cause eye injuries.

Compressed air systems are fabricated from brass and copper piping materials, bronze silver-brazed fittings, and bronze valves. Moisture and oil must be kept out of compressed air systems. Moisture is damaging to the piping and causes excessive wear in air-operated equipment. Oil is dangerous in high-pressure (600 psig and above) compressed air systems because it can form an explosive mixture with the air. Oil and moisture separation filters and, where necessary, air dryers are provided to remove these contaminating substances from the system.

The major air systems found aboard ship are (1) the high-pressure air system, (2) the ship's service air system, (3) gas ejecting systems, (4) starting and control systems for diesel engines, and (5) combustion control air systems.

The High-Pressure Air System

The high-pressure air system provides air at 3000 psi or 4500 psi for charging air banks. This system is also used at required pressure for services such as counterrecoil, diesel engine starting, gas ejection, torpedo charging, and torpedo workshops. When the service requires air at less than 3000 psi, the outlet from the high-pressure system is equipped with a reducing valve.

The Ship's Service Air System

The ship's service air system is a low-pressure compressed air system installed on practically all surface ships. This system normally uses a working pressure of 100 to 150 psi. This system supplies air at required pressures to operate pneumatic tools and oil burning forges and furnaces, to clean equipment, to pressurize electronic equipment wave guides with dehydrated air, and many other uses. The ship's service air system is normally supplied from a low-pressure air compressor. However, on some ships air may be supplied from the medium- or high-pressure system, through appropriate pressure reducing valves.

Gas Ejecting Systems

Gas ejecting systems, where required, supply air at the required pressure to the breeches of guns for removing gases and unburned solid matter. The standard working pressure of a gas ejection system is determined by the type of battery it supplies. Normally these systems will range from 100 to 200 psi. Air for the gas ejection system is supplied from the medium- or high-pressure system, through appropriate reducing valves.

Starting and Control System

A starting and control air system for diesel engines is installed on each ship that requires air for diesel engine starting and the control of equipment such as clutches, engine selector valves, turning gear, and propeller brakes. Air for this system is provided by a medium-range compressor at a pressure of 600 psi or from the high-pressure system, through appropriate reducing valves.

Combustion Control Air System

A compressed air system is installed on some steam-driven ships to provide air for the automatic combustion control system on the boilers. This compressed air system consists of an air compressor, air receiver, and piping to supply air for pneumatic units of the automatic combustion control system.

REFRIGERATION SYSTEMS

According to NAVSEA policy, refrigerants used in the Navy are no longer identified by trade names. Instead, they are identified by the letter *R* followed by the appropriate number, or else they are identified simply as refrigerants.

Most Navy refrigeration systems use R-12 as the refrigerant. Because of its low boiling point (-21.7°F at atmospheric pressure), R-12 is well suited for use in refrigeration systems designed for only moderate pressures. R-12 is neither flammable nor explosive. It is also noncorrosive to iron, steel, copper, brass, and Monel. Although the R-12 is practically nontoxic, you still have to be careful when using it. When it gets hot, it decomposes and produces products that are toxic, and can even kill you. Do not let anyone tell you that it is absolutely safe.

In the operating cycle of a refrigerating plant, the refrigerant gas is compressed and cooled to a liquid. It is then permitted to expand and become a gas again. The heat necessary to expand the liquid to a gas is obtained from the surrounding atmosphere of the space being cooled. It is this absorption of heat by the refrigerant that lowers the temperature of a refrigerated compartment. The amount of heat absorption is controlled by expansion valves and thermostats. The complete cycle is gas compression, condensation, controlled expansion in the space to be cooled, and return to the compressor.

The principal components of the system are the compressor, the condenser, the receiver, and the cooling coils (evaporator). Additional equipment required to complete the system includes piping, pressure gauges, thermometers, various types of control switches and control valves, strainers, relief valves, sight-flow indicators, dehydrators, and charging connections.

You are not responsible for maintaining and operating a refrigeration system. However, you may be required to assist a Machinist's Mate or an Engineman in making repairs or alterations to the refrigeration piping system.

PIPING SYSTEM MARKINGS

To make identification easy, piping systems are marked in some conspicuous location (preferably near control valves) and at suitable intervals so that every line carries at least one marking in each compartment through which it passes.

The identification markings include the name of the service, destination (where feasible), and direction of flow. These markings may be painted on by stencil or hand lettering, or on adhesive-backed tape that has been previously printed, stenciled, or lettered. These identifying marks are in letters 1 inch high for 2-inch or larger outside diameter pipe or insulation. For smaller sizes, the size of the letters may be reduced or label plates may be attached by wire or any other suitable means. In addition, a 3-inch arrow leads from the identification marking, with the arrowhead pointing in the direction of the flow. Where flow is reversible, arrows are shown on each end of the identification and destination markings.

Valves are marked by inscribing the rims of handwheels, on a circular label plate secured by the handwheel nut, or on label plates attached to the ship's structure or to the adjacent piping. Each valve label gives the name and purpose of the valve. For example, a valve may be labeled as follows:

DRAIN BULKHEAD STOP
2-85-1

The purpose of the valve is indicated in the first line. The location of the valve is indicated by the numbers in the second line. The first number in the location code indicates the deck (in this example, the second deck). The next number indicates the frame (in this example, frame 85). The last number indicates the side (in this example, starboard). Odd numbers are always used for the starboard side, while even numbers are used for the portside.

SUMMARY

As you work within the HT rating, you will gain more experience in pipefitting. You have learned in this chapter that a lot of factors need to be considered before you install or modify a piping system. This chapter gave you information on which materials to use, the types of hangers used, and the identification of piping and valves. Most shops have old and new valves and fittings on hand. Look over the valves and fittings to see how they operate. It will also be helpful to ask an experienced HT to help you. When working with insulation and lagging, make sure that you follow the procedures set forth in chapter 635 of *NSTM* and chapter B1 of OPNAVINST 5100.l9B, *NAVOSH Program Manual for Forces Afloat,* which include asbestos removal precautions and procedures.

CHAPTER 16

PIPING SYSTEM REPAIRS

LEARNING OBJECTIVES

Upon completion of this chapter, you will be able to do the following:

- *Describe the types of piping system repairs.*
- *Discuss some of the equipment used for piping system repairs.*
- *Describe the various techniques and procedures used in piping system repairs.*
- *Describe the repair and installation of piping system components.*
- *Describe the different types of marine mechanical pipe fittings.*
- *Discuss the procedures for shaping piping and tubing.*
- *Describe the procedures used in the maintenance and repair of valves used in piping systems.*
- *Describe the basic safety precautions to follow, and the hazards involved when performing piping system repairs on board ship.*

INTRODUCTION

As a Hull Maintenance Technician, you may repair fire main, flushing, steam, low-pressure air, fuel-oil, and other shipboard piping systems. Some repairs need nothing more than a composition seat in a water tap or a new gasket. Others are more complex. You may take down sections of the system, and fabricate and install entire assemblies or subassemblies.

When you repair any piping system, the requirements that governed the design and layout of the original system also govern the replacement sections. Before starting a repair job, be sure you know what that job requires. Do not substitute any unauthorized materials or change any fabrication and installation procedures.

As with any work you do, be sure to follow all of the proper safety precautions. Here are some of the standard precautions for piping repairs:

1. Make sure all piping systems are tagged-out, depressurized, and drained before you cut into the pipe or disconnect a joint.

2. Follow all OPNAV and shipboard instructions when performing tag-outs.

3. Ensure all piping systems open to the sea are properly isolated, gagged, or blanked off before working on the system.

4. When breaking a flanged joint, remove all bolts except the two opposing bolts. Gradually loosen the two remaining bolts to ensure that the system is properly depressurized and drained.

5. Ensure all flammable and toxic fluid or gas piping systems are properly drained, cleaned, and gas-free prior to working on the system.

6. NEVER exceed the operating capacities of shop equipment or hand tools.

7. Observe all safety precautions for welding, brazing, and other potentially dangerous processes used to repair piping systems.

8. NEVER substitute any material in a piping system without first obtaining proper authorization from competent authority. The use of unauthorized

material could cause the failure of the system and result in flooding, fire, equipment damage, even the loss of life.

9. Report any unsafe act or condition to your immediate supervisor before proceeding with the task at hand.

REPAIR OF PIPING

Repairs to piping systems are classified as permanent or temporary. The type of repair used depends upon the circumstances at the time the repairs are made. If the system can be secured, isolated, drained, and the necessary material is available, you should make permanent repairs. If not, then you should make a temporary repair to restore the system for use until permanent repairs can be made. Since temporary repairs are a damage control function in nature, this chapter will only discuss permanent repairs to piping systems. For further information on temporary repairs and to become proficient in their uses, it is highly recommended that you study the *Damage Controlman* training manual and qualify in DC PQS for pipe patching and repair.

PERMANENT REPAIRS

A repair is considered permanent if it meets two requirements. First, it must restore the piping system to its original service requirements. Second, it must be expected to last the life of the system.

The method of repair depends on several things. First, evaluate the nature of the damage. Next, consider the operating conditions of the system. Finally, consider the materials from which the system is made. Normally, you will replace the complete section of damaged piping or the damaged fitting. However, if the damage is minor, you can often make the repair by brazing, welding, or even patching. Permanent minor repairs made in this way will normally save you time and expense when compared with the replacement of the entire section of the system.

LAYOUT

Numerous details are involved in replacing a system or part of a system with new material. You will normally work from a blueprint, if available. If not, you will have to make your own plans or sketches. Whether you use blueprints or sketches, visualize what the completed job will look like. When you make your own plans, make sure your completed repairs will not interfere with other fixtures or the operation of other piping systems. Also, be sure you have enough of the materials on hand to complete the job before you start it. Blueprints contain lists of materials needed and the amount of each material required for that system or subsystem. If blueprints are not available, you will have to compute the amount of materials you need.

Measurements

Before you begin the work, make a diagram, and note on it the measurements of the new assembly. These measurements can be taken in any one or all of four ways: end-to-end, face-to-face, center-to-center, and end-to-center. Figure 16-1 illustrates these four methods of measuring pipe. The center-to-center method, by which a large number of measurements can be taken, is the method most commonly used.

Measurements give the overall picture. However, when actually cutting a length of pipe, you must add allowances to the “as taken” measurements. For example, a l/8-inch IPS threaded pipe will screw 1/4 inch into a threaded fitting. When computing the pipe length, you need to allow for that extra 1/4 inch. Figure 16-2 shows the amount of allowance required to make a tight joint for other sizes of pipe.

NOTE: Threaded fittings have a limited use in shipboard piping systems. They are not permitted in critical or hazardous systems.

A critical or hazardous system is defined as a system where a joint may fail and cause one of the following situations:

- Major damage to the ship

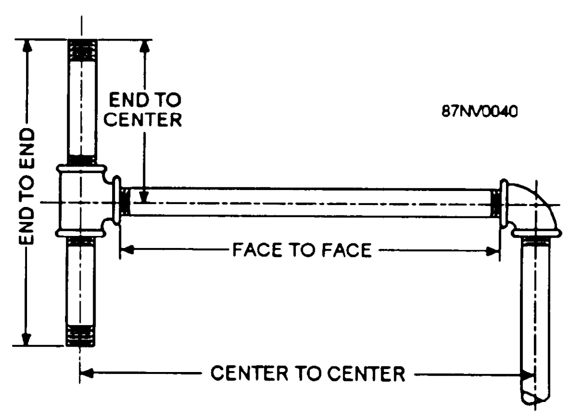
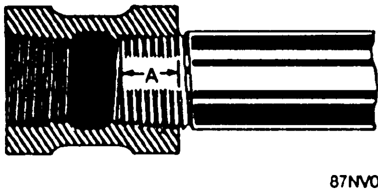


Figure 16-1.—Methods of measuring pipe.



Size of Pipe, inches	Dimension A, inches	Size of Pipe, inches	Dimension A, inches	Size of Pipe, inches	Dimension A, inches
1/8	1/4	1 1/2	1 1/16	5	1 1/4
1/4	3/8	2	3/4	6	1 5/16
3/8	3/8	2 1/2	15/16	7	1 3/8
1/2	1/2	3	1	8	1 7/16
3/4	9/16	3 1/2	11/16	9	1 1/2
1	11/16	4	11/8	10	1 5/8
1 1/4	11/16	4 1/2	13/16	12	1 3/4

Figure 16-2.—Length of thread on pipe required to make a tight joint.

- Serious injury to personnel
- Loss of a vital system that has no standby system

Where threaded fittings are not authorized, you will use a socket fitting. As in threaded pipe, you must add allowances to the "as taken" measurement of socket fittings before cutting a length of pipe. The allowances vary from brazed and welded socket fittings. In brazed fittings, you must add the depth of the socket to the length of pipe before cutting. In welded fittings, there are several special allowances to take into consideration when measuring your pipe. All welded piping systems, regardless of material or service, require the use of a small end gap clearance of l/l6 to l/8 inch between the pipe end and the fitting. This end gap clearance allows for thermal expansion of the pipe end in the socket. You must also take into consideration the reduced socket depth if you are reusing a welded socket fitting. When you remove the pipe from the fitting, you must remove part of the fitting to eliminate the fusion area of the weld, thereby reducing the socket depth. Refer to MIL-STD-22 for exact fit-up of welded joint designs. As you can see, allowances and measurements for socket fittings are more exact than those for threaded fittings.

Pipe Length Problems

The amount of pipe needed for a bend in a piping system must be computed during the layout stage. If the system permits bends to be used instead of elbows, make the necessary allowance for the extra pipe required to make the bend before you cut the pipe to size. The first step is to determine the bend radius, which should be as large as possible to prevent weakening of the pipe and restriction of fluid flow. Six times the pipe's diameter is a good rule, but there will be times when a smaller radius is required. Too small a radius will flatten the heel and wrinkle the throat of the pipe at the bend.

90-DEGREE PIPING BENDS.—You may determine the total developed length (TDL) of a section of piping with a 90-degree bend in three easy steps.

NOTE: All dimensions and points for the following excercise are taken from figure 16-3.

1. Subtract the bend radius from the straight section of pipe. Using the dimensions in figure 16-3, subtract 18 inches (bend radius) from 48 inches (straight section of pipe), which leaves 30 inches, the distance from points A to C. To get the distance from B to D, subtract 18 inches from 72 inches, which leaves 54 inches.

2. To figure out the total length of pipe for the bent 90-degree section of pipe, simply multiply the bend radius by a constant of 1.57. In this case, our bend radius of 18 inches multiplied by 1.57 gives us a total length of 28.26 inches for dimension AB in figure 16-3.

3. To get the TDL, the final step is to add the length of the legs to the length of the bent section (30" + 54" + 28.26" = 112.26"). At this point, you may convert the decimal measurement into a fraction for easier use in measuring a section of pipe.

PIPING BENDS OTHER THAN 90 DEGREES.—To compute the TDL for bends other than 90 degrees, a slightly different process is used. This

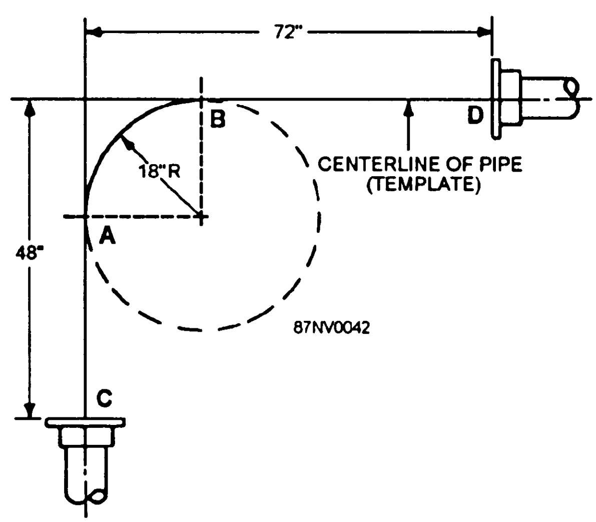
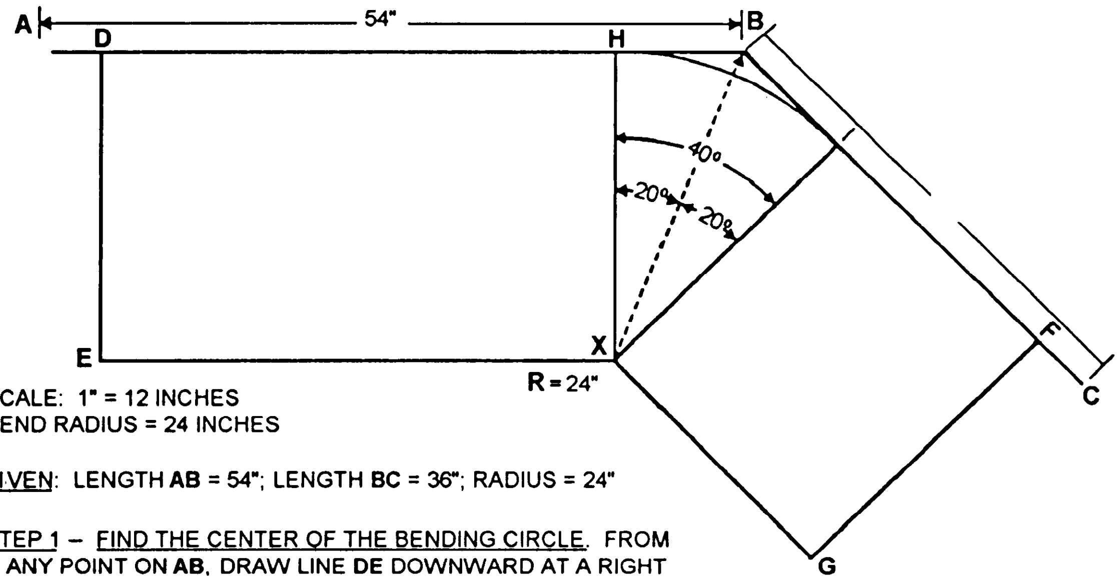


Figure 16-3.—Figuring the approximate length of pipe for a 90-degree bend.

BEND ALLOWANCE: LESS THAN 90°

PROBLEM: FIND THE TOTAL DEVELOPED LENGHT (TDL) OF PIPE NEEDED.



SCALE: 1" = 12 INCHES
BEND RADIUS = 24 INCHES

GIVEN: LENGTH **AB** = 54"; LENGTH **BC** = 36"; RADIUS = 24"

STEP 1 – FIND THE CENTER OF THE BENDING CIRCLE. FROM ANY POINT ON **AB**, DRAW LINE **DE** DOWNWARD AT A RIGHT ANGLE. (USE A PROTRACTOR FOR ACCURACY.) MEASURE A DISTANCE ALONG LINE **DE** EQUAL TO THE BEND RADIUS. CHECK THE SCALE (IN THIS PROBLEM, **DE** = 2"). AT POINT **E**, CONSTRUCT LINE **EX** AT A RIGHT ANGLE TO **DE** AND PARALLEL TO **AB**. FROM ANY POINT ON **BC**, DRAW **FG** DOWNWARD. AT POINT **G**, CONSTRUCT A LINE AT A RIGHT ANGLE TO **FG** AND PARALLEL TO **BC**. WHERE THESE TWO LINES INTERSECT, POINT **X**, IS THE CENTER OF THE BENDING CIRCLE.

STEP 2 – FIND THE LENGHT OF THE BEND SECTION. FROM POINT **X**, CONSTRUCT LINES AT RIGHT ANGLES TO **AB** AND **BC** TO POINTS **H** AND **I**. USING A COMPASS, DRAW AN ARC FROM **H** TO **I**. MEASURE ANGLE **X**–40°

FORMULA: BEND SECTION = $\frac{2\pi R \times \text{ANGLE}}{360} = \frac{6.2832 \times 24" \times 40°}{360}$ = **HI** = 16.76"

STEP 3 – FIND THE LENGTH OF OF **AH** AND **IC**.

AH = **AB** - **HB**; **IC** = **BC** - **BI**

NOTE: IN A RIGHT TRIANGLE, THE TANGENT OF AN ANGLE IS THE NUMERICAL RATIO OF THE LENGTHS OF THE SIDES OPPOSITE AND ADJACENT TO THE ANGLES.

TAN (ANGLE) = $\frac{\text{OPP}}{\text{ADJ}}$

FROM STEP 2, ANGLE X = 40°

TAN $\frac{X}{2}$ = TAN $\frac{40°}{2}$ = TAN 20° = .3640

.3640 = $\frac{\text{OPP}}{\text{ADJ}} = \frac{\text{HB}}{\text{BEND RADIUS}} = \frac{\text{HB}}{24"} = \frac{\text{BI}}{24"}$

HB = BI = .3640 (24") = 8.74"

AH = 54" - 8.74" = 45.26"

IC = 36" - 8.74" = 27.26"

HI (FROM STEP 2) = 16.76"

TDL **89.28"**

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Figure 16-4.—Bend allowance less than 90 degrees.

process is shown in figure 16-4 and in the following step-by-step exercise. Before continuing with this exercise, you will need a tangent table (table 16-l), compass, straight edge, calculator, protractor, paper, and a pencil.

NOTE: All dimensions and points for the following exercise are taken from figure 16-4. In this figure, a scale of 1 inch = 12 inches is used.

1. Find the center of the bending circle by drawing line DE down at a right angle from any point on line AB

Table 16-1.—Tangent Table

ANGLE	TANGENT	ANGLE	TANGENT	ANGLE	TANGENT	ANGLE	TANGENT
1°	0.0175	24°	0.4452	47°	1.0724	70°	2.7475
1°30′	0.0262	24°30′	0.5447	47°30′	1.0913	70°30′	2.8239
2°	0.0349	25°	0.4663	48°	1.1106	71°	2.9042
2°30′	0.0437	25°30′	0.4770	48°30′	1.1303	71°30′	2.9897
3°	0.0524	26°	0.4877	49°	1.1504	72°	3.0777
3°30′	0.0612	26°30′	0.4986	49°30′	1.1708	72°30′	3.1716
4°	0.0699	27°	0.5095	50°	1.1918	73°	3.2709
4°30′	0.0787	27°30′	0.5206	50°30′	1.2130	73°30′	3.3759
5°	0.0875	28°	0.5317	51°	1.2349	74°	3.4874
5°30′	0.0963	28°30′	0.5430	51°30′	1.2572	74°30′	3.6059
6°	0.1051	29°	0.5543	52°	1.2799	75°	3.7321
6°30′	0.1139	29°30′	0.5658	52°30′	1.3032	75°30′	3.8667
7°	0.1228	30°	0.5774	53°	1.3270	76°	4.0108
7°30′	0.1317	30°30′	0.5890	53°30′	1.3514	76°30′	4.1653
8°	0.1405	31°	0.6009	54°	1.3764	77°	4.3315
8°30′	0.1495	31°30′	0.6128	54°30′	1.4019	77°30′	4.5107
9°	0.1584	32°	0.6249	55°	1.4826	78°	4.7046
9°30′	0.1673	32°30′	0.6371	55°30′	1.4550	78°30′	7.9152
10°	0.1763	33°	0.6494	56°	1.4826	79°	5.1446
10°30′	0.1853	33°30′	0.6619	56°30′	1.5109	79°30′	5.3955
11°	0.1944	34°	0.6745	57°	1.5399	80°	5.6713
11°30′	0.2035	34°30′	0.6873	57°30′	1.5700	80°30′	5.9758
12°	0.2126	35°	0.7002	58°	1.6003	81°	6.3138
12°30′	0.2217	35°30′	0.7133	58°30′	1.6319	81°30′	6.6912
13°	0.2309	36°	0.7265	59°	1.6643	82°	7.1154
13°30′	0.2401	36°30′	0.7400	59°30′	1.6977	82°30′	7.5958
14°	0.2493	37°	0.7536	60°	1.7321	83°	8.1443
14°30′	0.2586	37°30′	0.7673	60°30′	1.7675	83°30′	8.7769
15°	0.2679	38°	0.7813	61°	1.8040	84°	9.5144
15°30′	0.2773	38°30′	0.8243	61°30′	1.8418	84°30′	10.3854
16°	0.2867	39°	0.8098	62°	1.8807	85°	11.4301
16°30′	0.2962	39°30′	0.8243	62°30′	1.9210	85°30′	12.7062
17°	0.3057	40°	0.8391	63°	1.9626	86°	14.3007
17°30′	0.3153	40°30′	0.8541	63°30′	2.0057	86°30′	16.3499
18°	0.3249	41°	0.8693	64°	2.0503	87°	19.0811
18°30′	0.3346	41°30′	0.8847	64°30′	2.0966	87°30′	22.9038
19°	0.3443	42°	0.9004	65°	2.1445	88°	28.6363
19°30′	0.3541	42°30′	0.9163	65°30′	2.1943	88°30′	38.1884
20°	0.3640	43°	0.9325	66°	2.2460	89°	57.2900
20°30′	0.3739	43°30′	0.9490	66°30′	2.2998	89°30′	114.5887
21°	0.3839	44°	0.9657	67°	2.3559		
21°30′	0.3939	44°30′	0.9827	67°30′	2.4142		
22°	0.4040	45°	1.000	68°	2.4751		
22°30′	0.4142	45°30′	1.0176	68°30′	2.5386		
23°	0.4245	46°	1.0355	69°	2.6051		
23°30′	0.4348	46°30′	1.0538	69°30′	2.6746		

using a protractor or compass for accuracy. Always draw your lines toward the inside of the bend. Measure a distance along line DE that is equal to the bend radius (point E). At point E, draw a line parallel to line AB. Repeat the same process for the other leg of your piping section to get line FG, point G, and a line parallel to line BC. The point where the two lines you have constructed cross is the center of the bending circle and should be labeled X.

2. Lay out the bend section by constructing lines that are at right angles from lines AB and BC that cross at point X. Label these points H and I. Now set your compass to the bend radius and strike an arc that touches points H and I on lines AB and BC. This arc is your bend section.

3. Use a protractor to determine angle X. Angle X should be 40 degrees. Use the formula (bend section = 2 × pi × radius × angle + 360) to determine the total length of the bend section. In this case, the bend section equals 2 × 3.1416 × 24 × 40 ÷ 360 or 16.76 inches.

4. To find the TDL, you still need to know the length of the remaining straight sections. You divide angle X (40 degrees) by 2 for an angle of 20 degrees. Now refer to table 16-1 to find the tangent for an angle of 20 degrees or 0.3640. Multiply the tangent (0.3640) by the bend radius (24) and you get 8.74 inches or the distance from BH and BI. Next subtract 8.74 inches from the distance of AB (54 inches) and from BC (36 inches) or 45.26 inches for AB and 27.26 for BC, respectfully.

5. The final step is to add the length of the legs to the length of the bend section (45.26" + 27.26" + 16.76" = 89.28") to get the TDL in inches. At this point, you may convert the decimal measurement into a fraction for easier use in measuring a section of pipe.

Therefore, a straight section of pipe 89 9/32 inches long, after proper bending, would fit the dimension AC of figure 16-4.

Flange Bolthole Layout

When you get ready to lay out boltholes in a flange, check your plan for the number of boltholes needed and the diameter of the pitch circle. A pitch circle is the circumference of the circle that will connect the center points of the boltholes. A pitch chord is the distance from the center of one bolthole to the center of the next. Here are the steps that you should use to lay out the boltholes in any given flange:

1. Scribe the pitch circle using the radius given in the plan.

2. Determine what the pitch chord is to be. This may be done geometrically or mathematically, or it may be listed in the plan.

3. Divide the circle into the desired number of equal parts as called for in the plan.

When the circle has been accurately divided, the points on the circumference of the circle will locate the centers of the boltholes. You can locate the center of the boltholes with a pair of dividers by adjusting the points. But this trial-and-error method is time consuming and not very accurate. Use the proper geometric construction described in the following paragraphs, and you can locate the bolthole centers more accurately and in less time.

The following problems illustrate the constructions used to lay out flange boltholes.

PROBLEM I—Lay out a five-hole flange. (See fig. 16-5.)

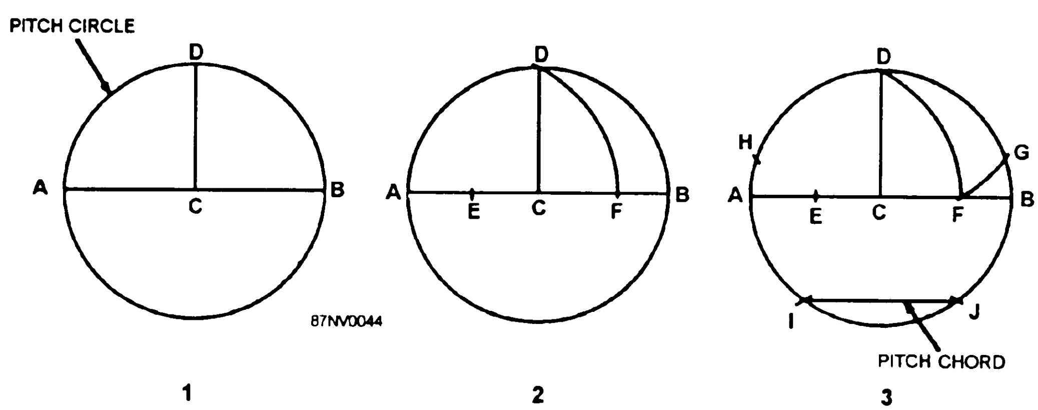


Figure 16-5.—Layout for a five-hole flange.

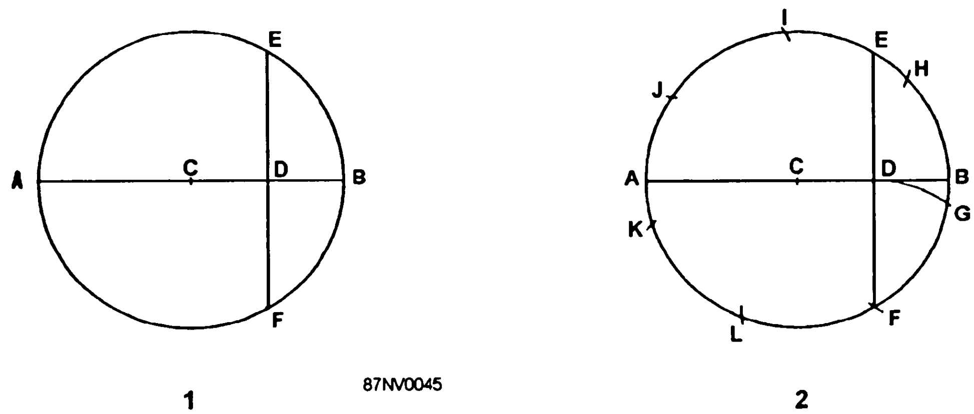


Figure 16-6.—Layout for a seven-hole flange.

SOLUTION:

1. Draw a circle of the required diameter (AB) and construct CD perpendicular to AB at center point C.

2. Bisect line AC, locating point E. Then with E as a center and distance ED as the radius, draw arc DE

3. With D as the pivot point and distance DF as a radius, scribe arc FG. Distance DF (or DG) is the length of the pitch chord and one-fifth of the circumference of the circle. Step off this distance (DF) around the circumference. Points G, D, H, I, and J are centers for the holes of a five-hole flange.

If you step off the circumference using measurement GB instead of DG, you get a 20-bolthole flange. Each spot where your dividers make an arc on the circle's circumference will be the center point for a bolthole.

PROBLEM II—Lay out a seven-hole flange. (See fig. 16-6.)

SOLUTION:

1. Draw a circle with the required pitch diameter (AB). Then construct a line that bisects and is perpendicular to radius CB (point D). Extend this line until it intersects the circumference at E and F.

2. With F as the center and distance DF as a radius, locate point G. Distance FG (also FD and DE) is one-seventh of the circumference or the true length of the pitch chord. With the dividers set for this distance, step off the circumference and locate points F, G, H, I, J, K, and L. These points are the centers for a seven-hole flange of the given pitch circle.

PROBLEM III—Lay out a nine-hole flange. (See fig. 16-7.)

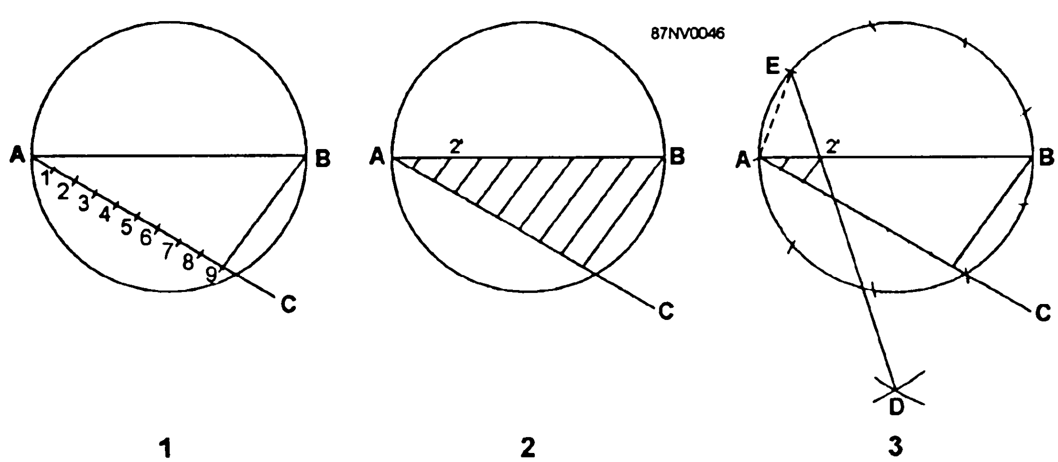


Figure 16-7.—Layout for a nine-hole flange or flanges having any number of holes.

SOLUTION:

1. Draw a circle with the specified pitch diameter. From A, at any convenient angle to the pitch diameter (AB), draw a line of indefinite length (AC). Adjust the dividers at any convenient setting and step off nine spaces along line AC. Draw line B9.

2. From points 1, 2, 3, 4, 5, 6, 7, and 8, construct lines parallel to B9, which intersect line AB. This procedure divides line AB into nine equal parts. The same principle can be used to divide a line of a specified length into any number of equal parts.

3. With distance AB as a radius, scribe arcs from A and B, establishing point D. From D, draw a line that passes through 2´ (on line AB) to the circumference at E. Distance AE is the pitch chord and the length of arc AE is equal to one-ninth of the pitch circle.

The principles illustrated in figure 16-7 and discussed in problem III may be used to lay out a flange with any number of holes. The division of line AC is the variable of the layout. Just set the dividers to a convenient distance and step off spaces equal to the number of boltholes desired. If you want 13 boltholes, divide line AC into 13 equal spaces. The second space point (2´ in fig. 16-7) is al ways used for the construction of line D2'E and the location of point E. If a pitch circle is difficult to divide into the required number of spaces, this method can be used to advantage. However, it is a lengthy construction. The layouts for five- and seven-hole flanges are easier to develop and have greater accuracy.

Developments for four-, six-, eight-, and ten-hole flanges are relatively simple. To determine the length of the pitch chord for a four-hole flange, construct two bisectors that intersect at 90-degree angles. For six-hole flanges, the radius of the pitch circle is equal to the length of the pitch chord. Step off that distance on the pitch circle to lay out the flange boltholes. For eight- or ten-hole flanges, bisect the pitch chords of the four- or five-hole layouts.

The exact distance to set dividers for a certain number of holes on a specified pitch circle can be determined by simple multiplication. However, a constant value for the desired number of boltholes must be known. The diameter of the pitch circle multiplied by the constant value equals the length of the pitch chord. The constant value for a specified number of holes is given in table 16-2.

Here is an example of the use of table 16-2. Assume that you need a flange with 11 boltholes and a pitch diameter of 10 inches. From the table, select the constant value for an 1 l-hole flange. The pitch diameter (10 inches) multiplied by the constant (0.28 17) equals the length of the pitch chord (2.817). Set your dividers to measure 2.817 inches, from point to point. Now step off the circumference of the pitch circle to locate the centers of the flange boltholes.

Table 16-2.—Constant Values for Locating Center of Flange Boltholes

Boltholes	Constant
3	0.866
4	0.7071
5	0.5 878
6	0.5
7	0.4338
8	0.3827
9	0.342
10	0.309
11	0.2817
12	0.2588
13	0.2394
14	0.2225
15	0.2079
16	0.195
17	0.184
18	0.1736
19	0.1645
20	0.1564

You will find the mathematical method using table 16-2 to be a rapid and convenient way to lay out flange boltholes. However, you should also be able to use the geometric construction method. You will not always have a table of constant values available, and some problems are not easily solved by the simple multiplication process.

Boltholes are not the only holes you will have to lay out. At times, pipe will pass through decks and bulkheads at an angle other than 90°. When this happens, you will need to develop an ellipse. This can be done in several ways; however, problem IV illustrates the geometric development.

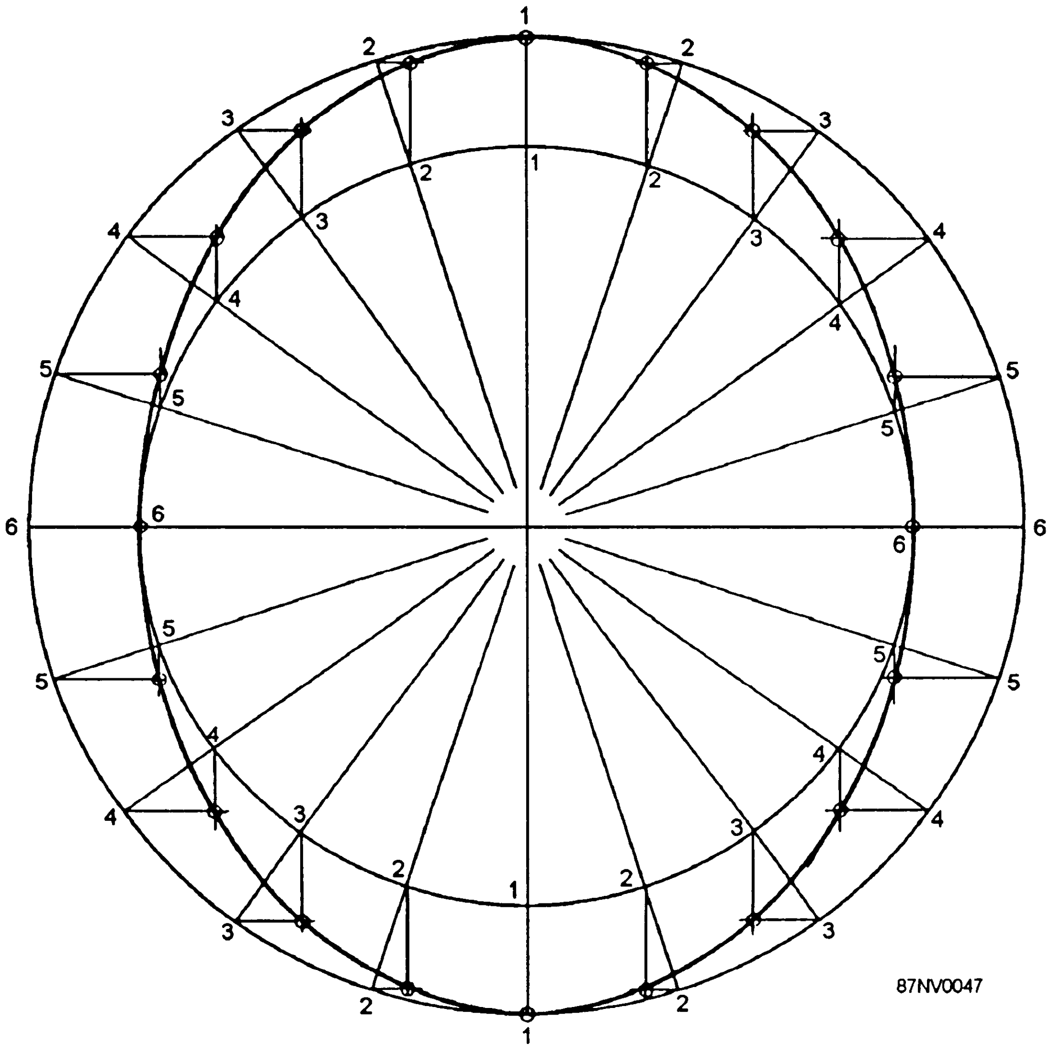


Figure 16-8.—Construction of an ellipse.

PROBLEM IV—Develop an ellipse with a vertical diameter of 6 l/4 inches and a horizontal diameter of 4 7/8 inches. (See fig. 16-8.)

SOLUTION:

1. Scribe a circle with a 6 l/4-inch diameter.

2. Use the same center and scribe a circle with a 4 7/8-inch diameter.

3. Develop the inner circle so that each quadrant or quarter-circle is equally divided into five parts. (See problem I and fig. 16-5 .)

4. Locate the equal-space division points on the outer circle circumference by radiating lines from the center point. These lines are to pass through the division points on the inner circle's circumference. Number these points as indicated in figure 16-8.

5. From each point on the inner circle, and parallel to diameter l-l, draw a line toward the outer circle.

6. From all points on the outer circle, draw lines parallel to diameter 6-6 so that they intersect with the lines drawn in step 5.

7. The points of intersection of the vertical and horizontal lines in each quadrant are points on the ellipse.

8. Sketch in the outline of the ellipse by freehand drawing, or use a french curve. A true and perfect ellipse must be developed geometrically. The greater the number of points established, the more nearly perfect the ellipse will be.

Sometimes the ellipse does not have to be perfect. In such cases the ellipse is laid out directly on the deck

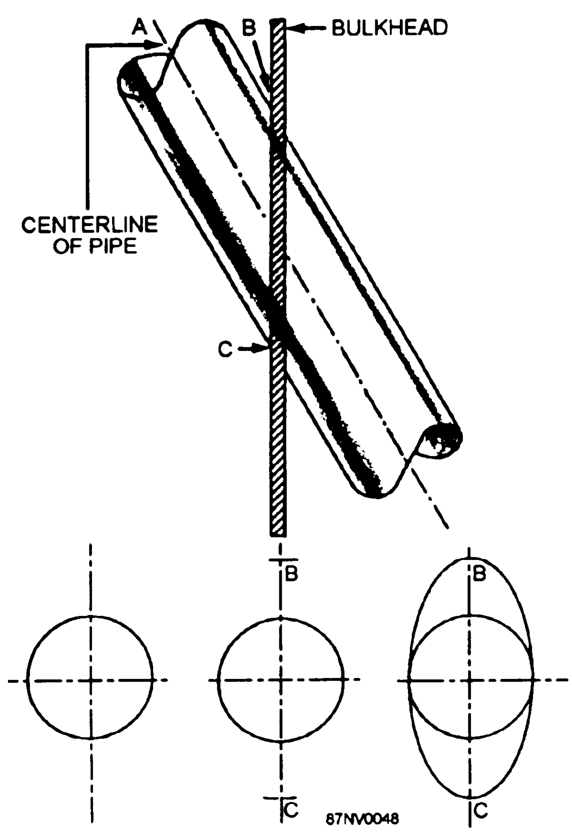


Figure 16-9.—Finding the length of an elliptical hole.

or bulkhead. The method used is shown in figure 16-9 and described in the following paragraphs.

Draw a line to represent the deck or bulkhead that the pipe will pass through. Use a protractor to lay out and draw a line at the angle that the pipe will pass through the deck or bulkhead. Draw this line as the centerline (A) to represent the center of the pipe. Then draw a parallel line on each side of the centerline. The distance between the parallel lines and the centerline is equal to one-half the outside diameter of the pipe or tube. This measurement must be made perpendicular from the pipe centerline. Measure the distance from B to C on the bulkhead line. This distance is the long axis of the elliptical hole.

Locate the halfway point between the two points marked B and C. This is the center point of the hole to be cut. Through this point, draw a horizontal line at right angles to the line representing the bulkhead. With a pair of dividers, scribe a circle equal to the outside diameter of the pipe. Then set the dividers at a radius equal to one-half the distance from B to C. Now scribe an arc across the long axis of the ellipse above and below the center point. Sketch in the remainder of the ellipse. You now have a useable layout for a pipe to pass through a deck or bulkhead at an angle.

MAKING TEMPLATES AND TARGETS

Frequently, the section of pipe to be replaced will have a bend in it. The replacement section will have to be exactly like the portion that is removed. You can get an exact fit by using templates and targets.

Templates are made from wood, wire, or small tubing. You will find them valuable in preparing new installations, as well as in repair work When properly made and correctly used, they provide an exact guide for bends and flange positions. The method of making and using a template is illustrated in figure 16-10.

A wood template is formed by securing blank wooden disks to the flanges of the fixed-position pipes. This is shown in view A of figure 16-10. Insert gaskets of the proper thickness between the wooden disks and the fixed flanges. This will provide the proper clearance for the permanent gasket installation. Next cut a 2 by 4 to fit snugly between the flanges. Secure the 2 by 4 by nailing triangular wood braces to the wood flanges and to the 2 by 4. The template can now be taken to the shop. A target (or reverse template, as it is sometimes called) can now be made. (See fig. 16-10, view B.)

Targets can be made of wood, but metal is the preferred material (fig. 16-10, view C) due to its durability, strength, and flame resistance. The targets are constructed of ordinary or blank flanges welded to angle iron or pipe. The target is then welded a minimum of 12 inches off of a target deck (a large metal slab) to make it easier to work on the new section of pipe. The target is then braced to prevent movement while working with the target. Remember, the target is your permanent pattern by which you are working off of and any movement, however so slight, will cause mis-alignment in your finished product. Only after the piping assembly has been manufactured, tested, and installed may you remove the target from the target deck. The target deck can then be used over again for another target.

In repair work, the target is usually made directly from the section being repaired. The pipe section then serves as the template. This procedure is illustrated in view D of figure 16-10.

A centerline template is made to conform to the bend, or bends, of the pipe to be made. It is used to lay

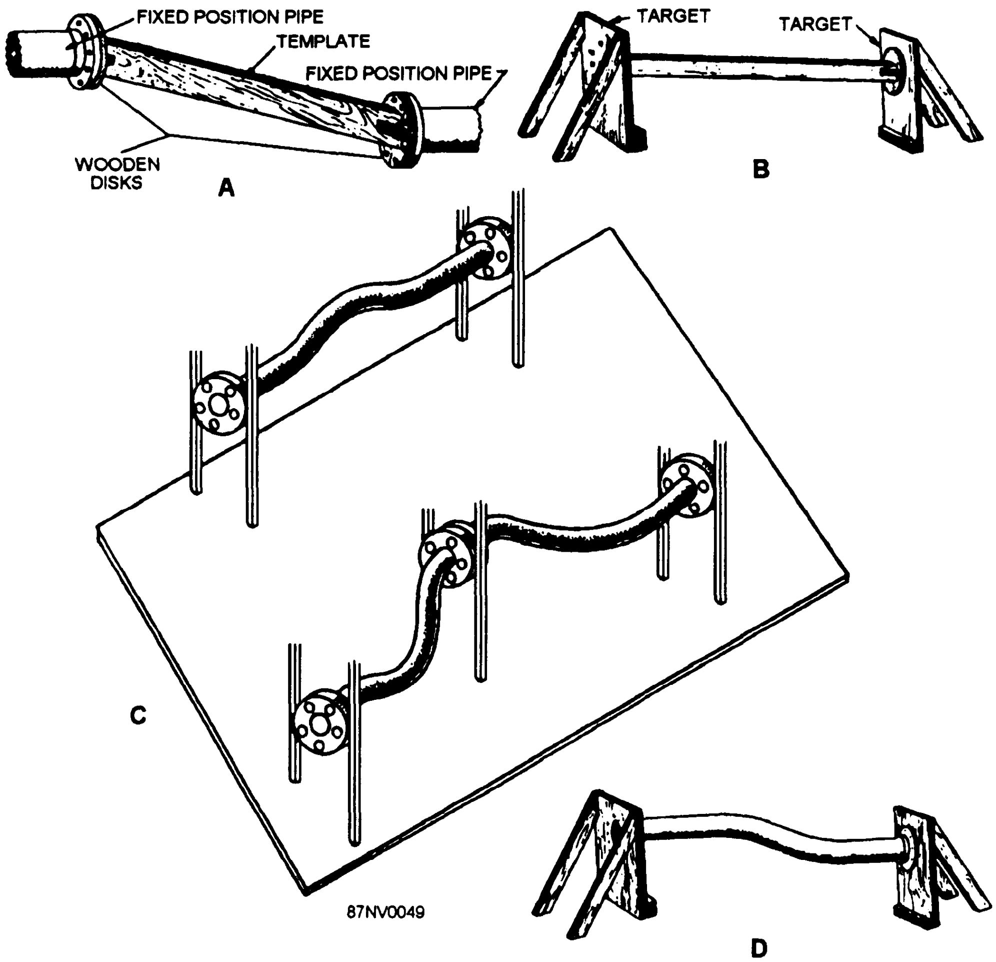


Figure 16-10.—Templates and targets.

off the bend areas on the pipe. It is also used as a guide during the pipe or tube bending operation. Figure 16-11 illustrates the use of a centerline template. These templates are made of rod (one-fourth or three-eighths inch in diameter), and are shaped to establish the centerline of the pipe to be installed. The ends of the rod are secured to special clamps called flange spiders. A sheet metal clearance disk is used if there is any doubt about the clearance around the pipe. The clearance disk must be the same diameter as the pipe being installed.

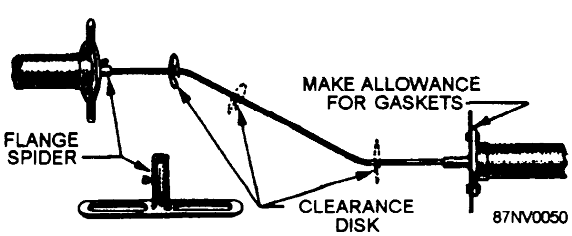


Figure 16-11.—Centerline template.

PIPE BENDING

Pipe made of steel, aluminum, nickel-copper, or copper-nickel should not be bent to a radius less than two times the diameter of the pipe. Copper and brass pipe may be bent to a radius one-and-a-half times the diameter.

Pipe may be bent using a power pipe bender or hot bent on a slab.

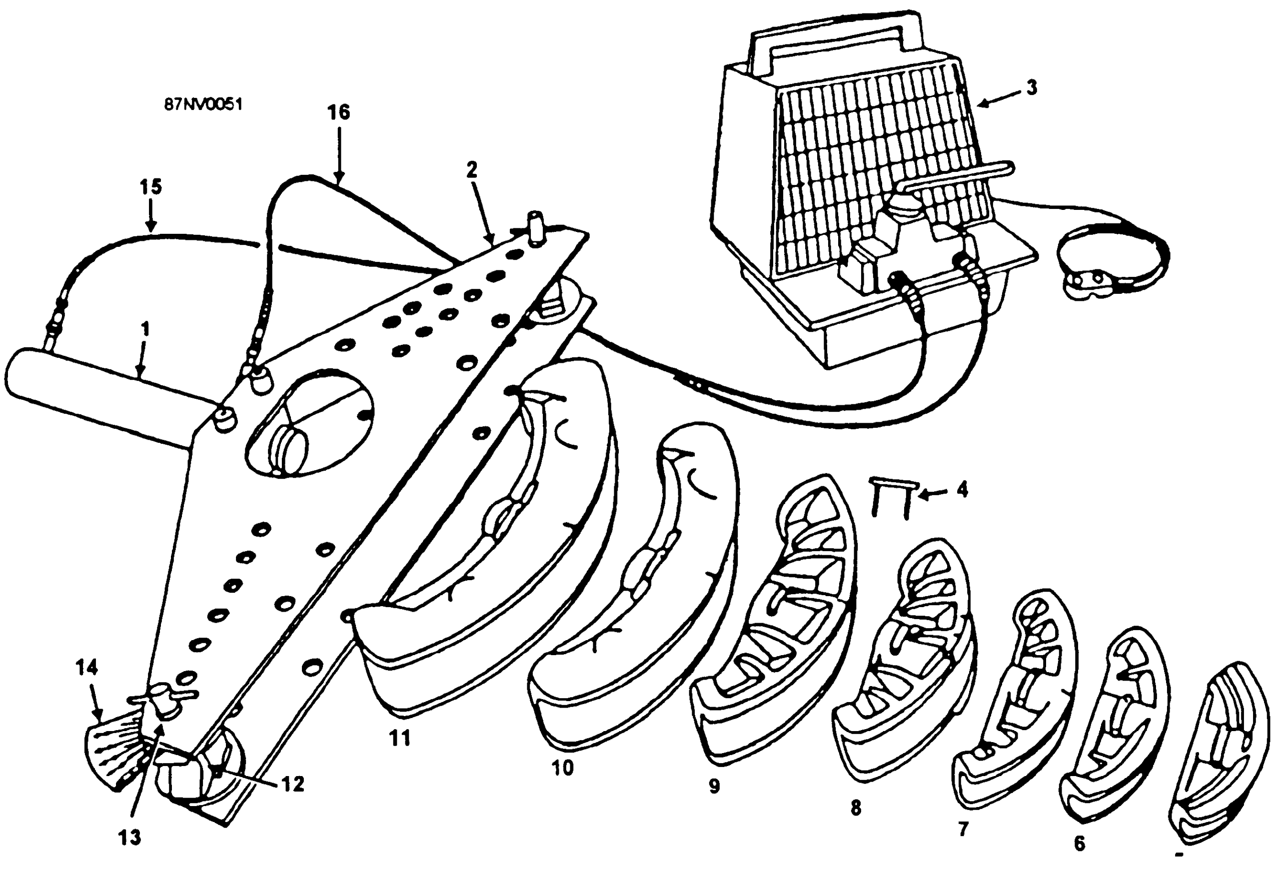
Power Pipe Benders

Cold bends in pipe or tubing are usually made in a bending machine, rather than on a slab. Various types of bending tools are available. They range from portable hand sets to large hydraulically driven machines that can bend up to 16-inch pipe. In this section, we will discuss the portable pipe bender and the rotary bender. Hand-held tubing and pipe benders will be discussed later in this chapter.

PORTABLE PIPE BENDERS.—Portable pipe benders, commonly referred to as one-shot benders, are lightweight, hydraulic-powered, portable units that can be taken to the job site so that pipe can bent on site rather than in the shop. Portable pipe benders are designed to work with pipe up to 5 inches and are capable of being operated by one person. If properly used and maintained, they can produce acceptable bends in all types of pipe and tube.

The portable pipe benders have two major components: the bender frame, with a removable hydraulic cylinder, and a hydraulic power unit (see fig. 16-12). The hydraulic power unit is connected to the hydraulic cylinder with flexible hydraulic hoses. Bender control is accomplished by a three-position (off, advance, and retract) valve located on the hydraulic unit. Bending is accomplished by the use of a bending shoe attached to the ram of the hydraulic cylinder and two pivot shoes pinned in the frame. Bending shoes must be changed to match the size of pipe being bent. Pivot shoes are marked for various pipe sizes and are simply rotated in the frame to match the size of pipe being bent. They may also be required to be moved to different settings in the frame to match pipe diameter. An optic angle gauge is provided to measure the degree of bend in the pipe.

After the machine is set up, you are ready to bend a section of pipe. Simply mark the center of your bend on a section of pipe and insert it into the bending shoe. Ensure that it extends beyond the pivot shoes a sufficient distance. If the pipe is cut too short, it could slip off the pivot shoes while being bent due to the stretching of the pipe. Align the mark on your pipe with the arrow on the bending shoe and snug the pipe into the shoes. Check your angle gauge; it should read zero along the line scribe on the bender frame. Proceed to bend your pipe, watching the optical angle gauge until the desired angle of bend is reached. When the bend is complete, retract the cylinder and remove the section of pipe.



1. **Hydraulic cylinder**
2. **Bender frame**
3. **Pump and hoses**
4. **Shoe lock pin**
5. **1 l/4-in. shoe**
6. **1 1/2-in. shoe**
7. **2-in. shoe**
8. **2 1/2-in. shoe**
9. **3-in. shoe**
10. **3 l/2-in. shoe**
11. **4-in. shoe**
12. **Pivot shoes**
13. **Pivot pins**
14. **Optic angle gauge**
15. **Bend pipe hose**
16. **Eject pipe hose**

Figure 16-12.—Portable pipe bender components and assembly.

After removing the section of pipe, check for defects such as flat spots, wrinkles, out-of-roundness, pitting, marring of the pipe surface, and the bend angle. To correct overbend in a section of pipe, simply reverse the pipe in the bender frame. Reposition the pivot shoes and pins to the overbend correction holes. One pivot shoe should be on the straight end of the pipe and one at the other end of the bend to provide proper support for the pipe as shown in figure 16-13. Inch the bending shoe forward a few degrees at a time until the desired correction is made.

Flat spots, wrinkles, and out-of-roundness is a common problem encountered when using a portable bender since the pipe is usually bent without any internal support. To eliminate these defects, you may find it easier to make several smaller bends than one large bend. By making several smaller bends, you spread the stress of bending over a larger area and reduce the amount of force required to make the bend. Care must be taken to reposition the pivot shoes after every bend so that they are always in contact with the pipe.

ROTARY PIPE BENDERS.—Rotary pipe benders are capable of bending 16-inch diameter pipes or larger. Most tenders and shore facilities are equipped to bend pipe in the 4- to 6-inch diameter range. Shipyards are equipped with machines of larger capacity. This installed machinery must be operated by three or more persons. Rotary pipe benders are the preferred machine to bend pipe due to their accuracy, versatility, and quality of bend.

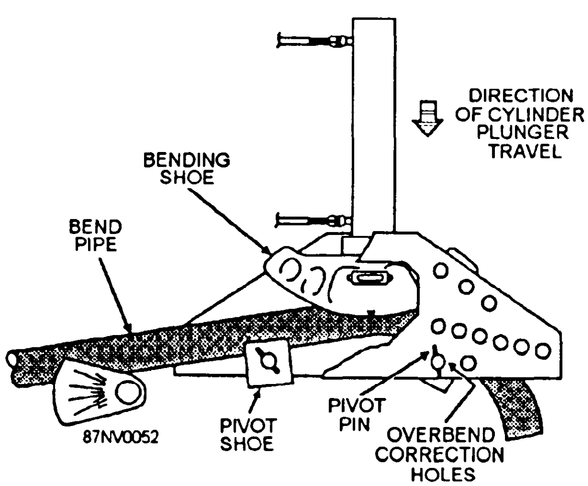


Figure 16-13.—Correcting overbend.

Rotary pipe benders are larger and much more complex machines than the portable pipe bender. They use up to four dies and a hydraulic cylinder to perform the bending operation. These benders also may use a mandrel to provide internal support to the pipe wall during the bending evolution to prevent collapse and wrinkling of the pipe.

To properly set up a rotary bender, you must become familiar with the different dies used on these machines and their functions (see fig. 16-14). They are as follows:

- BEND DIE—The centrally located die that is rotated by a hydraulic cylinder to bend the pipe.
- CLAMP DIE—The die that clamps the pipe to the bend die.
- PRESSURE DIE—The die that provides support and acts as a backstop to the pipe during the bending evolution.
- WIPER DIE—The die that provides support in the throat of the pipe and guides the pipe into the bend die. Proper use of this die greatly reduces winkles in the throat of the bend.

Choose the dies according to the diameter of the pipe and the bend radius. These measurements should be stamped on the die. Since pipe and tube have different outside diameters for the same size of material, choose your dies carefully to prevent damage to the equipment, pipe, or personnel.

After choosing your die, you are ready to set up the rotary bender. Place the bend die over the die stud and align the keyway on the die with the die key on the machine. Tap the bend die gently in place, install the nut on the die stud, and tighten. Next, install the clamp die.

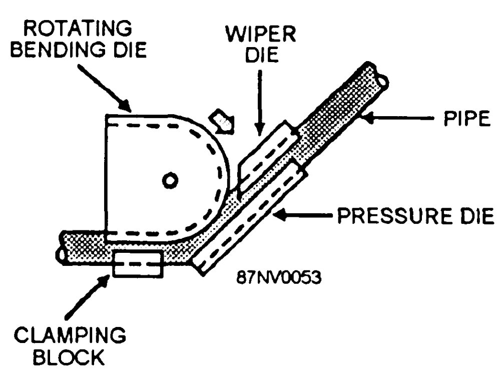


Figure 16-14.—Positioning of rotary pipe bender dies.

There arc two basic types of clamp die installation: manual and hydraulically actuated. The manual-actuated clamp die is a simple-hinged die holder that is swung up into place. The holding power is provided by a yoke assembly and setscrew that is fastened to a retaining post that is bolted to the bend die. The hydraulically actuated clamp die is also bolted to the bend die and uses a series of linkage to operate the clamp die. A small hydraulic cylinder applies pressure to the linkage to firmly clamp the pipe to the bend die. When setting up and adjusting the clamp die, use a sample piece of pipe of the same diameter as the pipe to be bent to act as a gauge. Ensure that the face of the clamp die is not bottomed against the bend die. If it is bottomed, no clamping pressure will be applied to the pipe to be bent.

The next step is to install the pressure die. The pressure die is mounted to a movable pressure die holding bar to allow the pressure die to slide forward with the pipe as it is bent. The die holding bar is mounted on a slide keyway and is either manually or hydraulically operated. Loosely mount the pressure die on the holding bar and bring the die up to a sample pipe clamped in the clamp die. Align the pressure die to the pipe and tighten the pressure die mounting bolts. The pressure die is never adjusted with as much pressure as the clamp die. It is designed to provide support to the pipe not clamping action. Ensure that there is clearance between the pressure die and the bend die.

The final die to bc installed is the wiper die. The wiper die is an optional die, and its use is determined by the wall thickness of the pipe, the degree of bend, and operator preference. It is mounted in front of the bend die to guide the pipe into the bend die. There are no special adjustments for the wiper die.

If you are bending thin wall pipe or tubing, or making short radius bends, you may want to USC a mandrel to support the wall of the pipe. By supporting the pipe wall, the mandrel reduces the flattening and wrinkling of the pipe during the bending evolution. Mandrels may either be rigid or flexible. The rigid type provides support only at the tangent (start) of the bend. The clearance between the rigid mandrel and the pipe should not exceed 20 percent of the wall thickness of the pipe. Flexible mandrels, on the other hand, provide support throughout the bend area. Clearance for flexible mandrels range from 0.001 to 0.095 inch. Choose the mandrel that best meets the requirements of the job at hand.

After choosing the proper mandrel, thread the mandrel onto the mandrel rod and tighten. Again, the mandrel may be adjusted hydraulically or manually, depending on the type of machine used. You should position the tip of the mandrel at approximately the tangent point of the bend. Once the mandrel is positioned, do not change its setting during the bending evolution. If using a flexible mandrel, ensure that all segments of the mandrel bend in the directionof the pipe bend. After the machine is set up, you are ready to bend your pipe.

Select your pipe carefully, ensuring that it is free of noticeable defects and blemishes. The pipe should then be cleaned to remove all grease, oil, scale, and rust. If using a mandrel, use a lard- or a lanolin-based lubricant to coat the mandrel before inserting the pipe over the mandrel. Never use petroleum-based products to lubricate the mandrel. Insert the pipe over the mandrel, if used, ensuring that it slides freely, and clamp the pipe in place. Next, bring the pressure die in contact with the pipe. Before bending, draw a pencil mark around the pipe at the face of the clamp die. During the bending operation, watch the pencil mark for signs of slippage. If slippage is allowed, you will get wrinkles in the pipe. Severe wrinkles will break the pipe and damage the mandrels if the bending motion is not stopped immediately. Set the automatic stop on the machine 2 or 3 degrees over the desired degree of bend (this allows for spring-back in the pipe after the pressure die is removed), and slowly bend the pipe. After bending the pipe, back out the mandrel and remove the pipe from the dies.

POWER PIPE BENDER SAFETY.—The following are some of the more common safety practices used with power pipe benders:

- Always wear proper safety equipment, especially safety glasses and hearing protection.
- Know your specific equipment and qualify on its operation.
- Never exceed equipment capacity.
- Cycle the machine through a complete cycle prior to loading the pipe. Check for smooth operation and ensure all installed equipment is firmly fastened.
- Never attempt to bend pipe alone, especially on rotary benders.
- When using the portable pipe bender, do not stand in front of the ram during the bending evolution. If the pipe slips or the frame and pins Fail, you could be seriously hurt.

Hot Bending

For hot bends, the bending slab (fig. 16-15) will probably serve you best. This slab requires little maintenance beyond a light coating of machine oil to keep rust under control. As a preliminary step in hot bending, pack the pipe with dry sand. Drive a tapered wooden plug into one end of the pipe (as shown in fig. 16-16). Place the pipe in a vertical position with the plugged end down. Then fill it with dry sand, leaving just enough space at the upper end to take a second plug. This will help to prevent the heel or outside of the bend from flattening. If flattening occurs, it will reduce the cross-sectional area of the pipe, and restrict the flow of fluid through the system. Ensure that the sand is tightly packed. This is done by tapping the pipe continually with a wooden or rawhide mallet during the filling operation. A good rule of thumb is to tap 1 hour for each inch of pipe diameter. The second plug is identical with the first, except that a small vent hole is drilled through its length. This vent permits the escape of any gases (mostly steam) that may form in the packed pipe when it is heated. No matter how dry the sand may appear, there is always a possibility that some moisture is present. This moisture will form steam, which will expand and build up pressure in the heated pipe. If you do not provide a vent, one of the plugs will blow out before you can get the pipe bent.

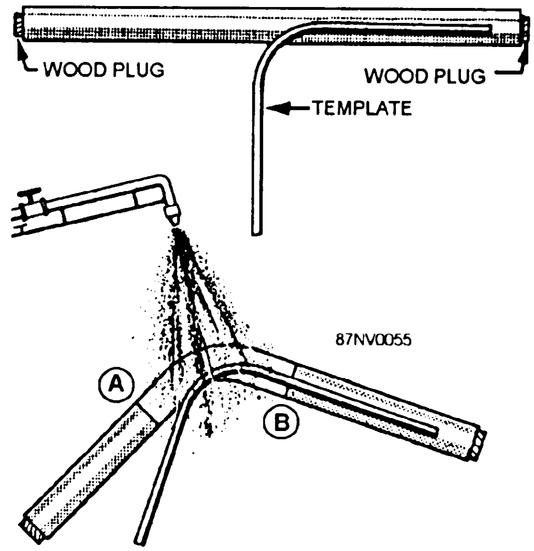


Figure 16-16.—Heating and bending pipe to conform to the wire template.

Once you have packed the pipe with sand, mark the bend area of the pipe with chalk or soapstone. Then heat the pipe to an even red heat along the distance indicated from A to B in figure 16-16. Apply heat to the bend area first on the outside of the bend and then on the inside. When an even heat has been obtained, bend the pipe to conform to the centerline template. The template is also used to mark the bend area on the pipe. When bending steel and some other piping materials, you can control wrinkles and flat spots by first overbending the pipe slightly, and then pulling the end back as shown in figure 16-17.

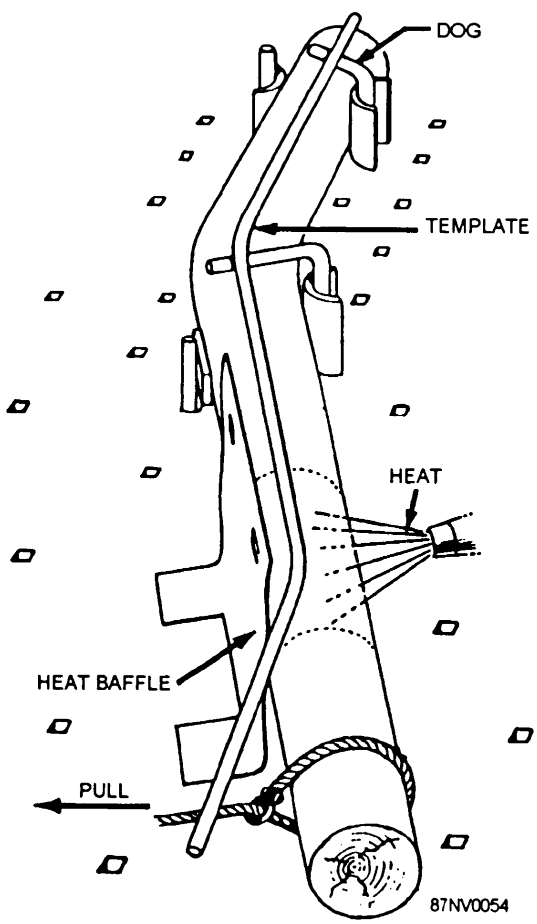


Figure 16-15.—Bending on a slab.

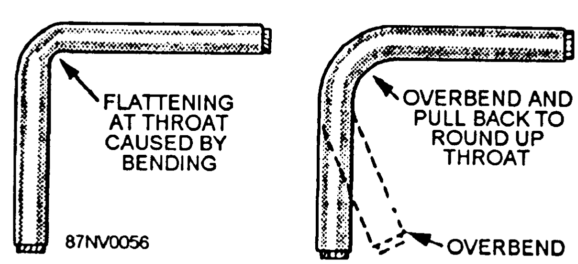


Figure 16-17.—Overbending to prevent flattening of pipe.

Most hot bends are made on a bending slab (as shown in fig. 16-15). To make the bend, exert the pull in a direction parallel to the surface of the bending slab. The necessary leverage for forming the bend is obtained by using chain-falls or block and tackle. Or you can use a length of pipe that has a large enough diameter to slip over the end of the packed pipe. Bending pins and hold-down clamps (dogs) are used to position the bend at the desired location.

Be sure to wear gloves when you are working on hot bending jobs. You will occasionally need to move the pins, clamps, and baffles during the bending operation. These items absorb heat radiated from the pipe as well as from the torch flame itself. You cannot safely handle these bending accessories without gloves.

Each material has its peculiar traits. You will need to know about these traits to get satisfactory results. The following hints for bending different materials should prove helpful :

WROUGHT IRON—This material becomes brittle when hot, so always use a large bend radius. Apply the torch to the throat of the bend instead of to the heel.

BRASS—Do not overbend. Brass is likely to crack or break when the bend direction is reversed.

COPPER—Hot bends may be made in copper, although the copper alloys are more adaptable to cold bending. This material is not likely to give you any trouble.

ALUMINUM—Overbending and reverse bending do not harm aluminum. However, there is only a small range between the bending and melting temperatures. Therefore, you will have to work with care. Keep the heat in the throat at all times. You will not be able to see any heat color. You will have to depend on “feel” to tell you when the heat is right for bending. You can do this by keeping a strain on the pipe while the bend area is being heated. As soon as the bend starts, flick the flame away from the area. Play it back and forth to maintain the ending temperature and to avoid overheating.

CARBON-MOLYBDENUM and CHROMIUM-MOLYBDENUM—These may be heated for bending, if necessary. However, use caution so you do not overheat the bend area. These metals are easily crystalized when extreme heat is applied. Pipes made from these materials should be bent cold in either manual or power bending machines.

Post Pipe Bending Inspection

All piping, regardless of the method used to bend the pipe, should be inspected after bending for defects and to meet the requirements of MIL-STD-1627. The surface should be free of pits, gouges, scratches, or tool marks. Defects are acceptable if they are less than 0.010 inch or 5 percent to the nominal thickness of the pipe, whichever is greater. The depth of the defect should not reduce the pipe wall thickness below its minimum requirement. You may remove defects exceeding the depth limits by faring in, grinding, or buffing to a radius 3 times the depth. The final pipe wall thickness after defect removal must meet minimum thickness requirements.

Wrinkles in the pipe wall are unacceptable. However, buckles, bulges, and dents may be acceptable if they meet the following criteria:

- Buckles, bulges, and dents must blend in smoothly.
- The maximum vertical height of any buckle, bulge, or dent must not exceed 3 percent of the nominal pipe outside diameter.
- The diameter-to-height ratio must equal or exceed 12 to 1.

Out-of-roundness is another common defect found in pipe bends. To find out-of-roundness, use the following formula:

NOTE: All measurements should be taken with either vernier or dial calipers.

OD max - OD min $\times$ 100 divided by OD nom.

where:

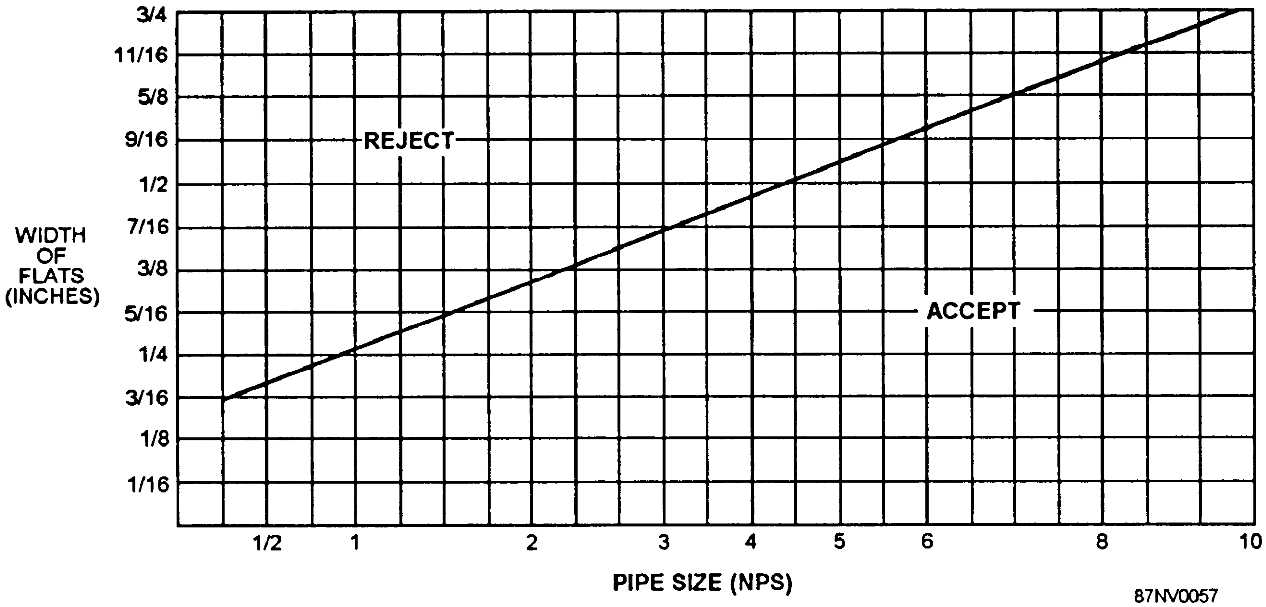
OD max = Maximum measured OD at the bend

OD min = Mimimum measured OD at the bend

OD nom = (OD max + OD min) divided by 2.

The maximum allowable out-of-roundness for pipe with a working pressure of 600 lb/in^2 and greater is 5 percent. For a pipe with a working pressure of less than 600 lb/in^2, the maximum allowable out-of-roundness is 8 percent.

Flat spots are the last defect you want to inspect the pipe for. Flatness is acceptable if it falls within the limits established by a flatness limits graph (see fig. 16-18). By measuring the width of the flat and knowing the pipe size, you can determine if the flat spot is acceptable or



PIPE SIZE EQUIVALENTS (NPS = OUTSIDE DIAMETER)

1/4 = 0.540	1 = 1.125	2 = 2.375	4 = 4.500	10 = 10.750
3/8 = 0.675	1-1/8 = 1.315	2-1/2 = 2.875	5 = 5.563	
1/2 = 0.840	1-1/4 = 1.660	3 = 3.500	6 = 6.625	
3/4 = 1.050	1-1/2 = 1.900	3-1/2 = 4.000	8 = 8.625	

Figure 16-18.—Flatness limits graph.

rejectable. If any pipe bend is rejected for any of the previously mentioned reasons, the pipe should be discarded and a new section of pipe bent.

ASSEMBLY AND DISASSEMBLY OF PIPING

A great many joints are used in shipboard piping systems. When standard fittings are used, such as couplings, elbows, and T-joints, threads must be cut on pipes and tubing. Pipe threads cause frequent failures and it is often difficult to remove threaded joints. For this reason, welded or brazed connections fitted with flanges or unions are used whenever possible. However, you will find threaded fittings used in flexible piping, in low-pressure systems, and with pipe of 2 inches IPS or less. Actually, a joint capable of withstanding 1000 psi can be made if perfect threads are cut and if the joint is properly assembled.

Threaded Joints

Pipe threading is a precise machining operation. Perfect threads are possible only if the threading dies are in good condition and properly used. Even with a perfectly cut thread, you will not get a sufficiently tight joint unless every step is done properly.

Sometimes a leaking threaded joint can be tightened with a reasonable amount of pull-up. If it cannot, you will have to take the joint apart, clean it, correct any bad thread conditions, recoat it with a suitable thread compound, and then reassemble it. When you do this, be careful to avoid new damage to the threads.

When you cut the pipe to the required length, there will be a burr on the inside. This will be true whether you use a cutting torch, a saw, or a pipe cutter. You will have to remove this burr with a file or a pipe reamer. (For more information on threading and reaming pipe, refer to chapter 5 of this manual.)

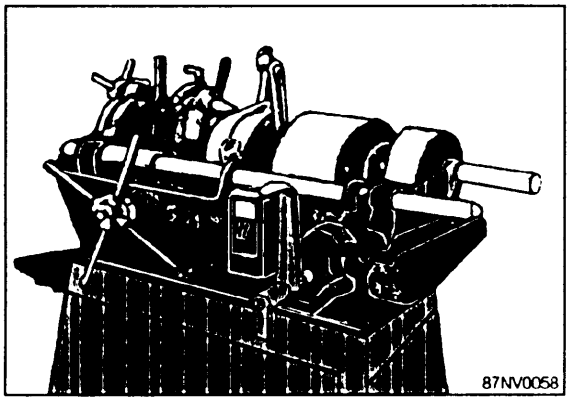


Figure 16-19.—Pipe cutting, burring, and threading machine.

The threading machine shown in figure 16-19 has the ability to perform threading, cutting, and reaming functions on pipe or bolt stock. The pipe or stock is inserted through the back of the machine into a motor-driven chuck or vise that securely holds and rotates the pipe or bolt stock. Several attachments are on the carriage assembly to perform the threading, cutting, and reaming functions of the threading machine.

The threading dies are mounted in a movable threading assembly. The assembly is fully adjustable and can accommodate pipe from l/8 to 2 inches (nominal) in size. As you move from one pipe size to the next, you will need to replace the dies as required for the work you are doing. All dies are stamped according to the range of pipe they can accommodate. Once you have selected the proper dies and set up the machine, you are ready to thread your pipe. As the pipe rotates in the chuck assembly, the die assembly is brought up to the stock to start the threading action by means of a handwheel on the side of the machine. You should not have to apply too much pressure to the handwheel to get the dies to engage the pipe since the dies are tapered to match the taper threads being cut on the pipe. Lubricant will flow from the sump as soon as the machine is started. If you fail to get a lubricant flow, check the petcock valve on the supply tube to ensure that it is on. Proper lubricant flow is required to ensure lubrication and cooling of the dies. Once the threading action is started, the die assembly will automatically draw itself along the length of the pipe until the desired amount of thread is cut. After you have cut the desired length of thread, disengage the die assembly by releasing the die clamp at the top of the die assembly.

Cut-off functions are performed by a pipe cutter (similar to hand-held pipe cutters) that is lowered onto the pipe from the carriage assembly. Reaming functions are performed by a reamer attached to the carriage assembly and inserted into the end of the pipe. All carriage attachments are mounted to swing out of the way when not being used. You can use the pipe threading machine to manufacture various size nipples as short as 4 inches and close nipples with the use of a nipple chuck.

When manufacturing nipples, you need to have an understanding of what constitutes a nipple. A nipple is a piece of pipe no longer than 12 inches and is threaded on both ends. Any pipe over 12 inches in length is a cut piece of pipe and not a nipple. A close nipple has threads the entire length of the nipple with no shoulders.

Another type of pipe and bolt threading machine is shown in figure 16-20. Here the pipe or bolt stock is held stationary and the dies are revolved. The arms of the machine may turn the handles of the die stock either by electric or pneumatic power. The thread is cut in the same way as by hand.

The tightness of a threaded joint depends upon good metal-to-metal contact. Use a wire brush to remove any dirt in the threads of either the male or female ends.

The secret of the proper assembly of a threaded pipe joint is to avoid friction between the metal parts. Friction during assembly produces heat, which in turn causes expansion. The threaded pipe, with its thinner wall, is more affected than is the fitting. When the parts

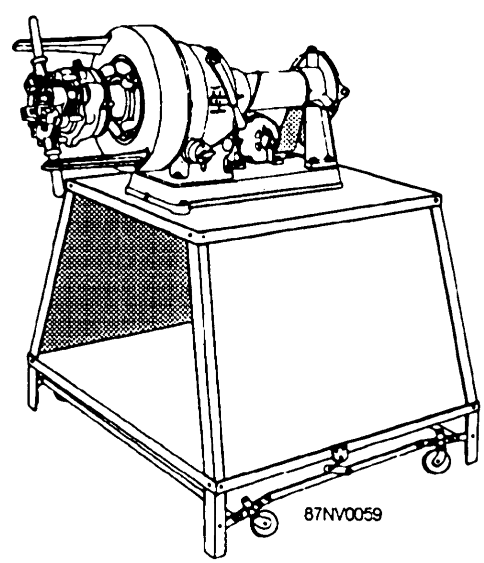


Figure 16-20.—Pipe and bolt threading machine.

cool, the pipe contracts more than the fitting, and a loose joint results.

Use good lubricant or pipe dope to overcome friction and make it easier to assemble parts. Paint the pipe dope on the male thread only. This is to keep it from getting into the pipe and damaging valve seats and other parts of the system.

White lead or red lead is generally used to lubricate and make up threaded joints in plumbing work. A special paste made from oil and filler material is used on some low-pressure steam lines. A compound or mixture of white lead and spar varnish is recommended for freshwater systems.

In assembling the joint, you will have to depend on feel to tell whether the male and female threads are properly started. Make up the joint by hand and turn the fitting as far as it will go. A few turns with the proper size pipe wrench should complete the job. It may be necessary to use a large wrench or a wrench handle extension when you are taking down lines with stubborn joints. But, an oversize wrench used to assemble the joint may crack the walls of the fitting.

Flanged Joints

The methods used to join a flange to a pipe are the same as those used with other fittings; that is, the flange may be welded, brazed, or screwed to the pipe. Male and female flanged joints are not generally used in steam piping. The initial cost of these joints is high, and it is difficult to disconnect them to replace gaskets. However, this type of joint is still used in hydraulic and other high-pressure lines, and for steel piping connections in high-temperature turbine lubrication systems. To get enough play in the line to break the joint, you will have to slack a slip joint or spring the line.

Flange faces must be in perfect alignment and free from all dirt and grit, which might cause trouble in the joint. In some instances, you may need to build up eroded areas of the flange by welding. Then the flange faces will need to be refaced before you can make a satisfactory joint. However, a thorough cleaning job will be enough for most flanges.

All faced and grooved flanges are assembled with gaskets. When choosing a gasket, always refer to the applicable system blueprint for the correct gasket. If the applicable blueprint is not available, refer to MIL-STD-777 or MIL-STD-438 to select a proper gasket. If none of these references are available, your gasket choice will depend on the characteristics, operating conditions, and mechanical features (bolting, flange shape, and so forth) of the flanged assembly. Since these factors are interdependent, carefully examine and weigh all factors for each installation.

Gasket cutters are made to cut gaskets from sheets of gasket material such as paper, cork, rubber, leather, and asbestos and fiber composition. One type of gasket cutter is shown in view A of figure 16-21. To use this cutter, place the gasket material on a wood surface and adjust the two cutters-one for the inside cut, the other for the outside cut. Place the shank in a brace and insert the center pin in the gasket material and rotate the brace, thereby forming the gasket. If the gasket is to have boltholes, punch them out with a gasket punch of the type shown in view B of figure 16-21. These punches are available in various sizes. Punching the boltholcs a bit larger than the bolts will eliminate a tendency toward bulging along the bolt circumference. The center material should be cut so that the inside diameter is the same as the inside diameter of the pipe at the flange surface.

Gaskets may also be cut with shears, snips, or a sharp knife. When using any of these tools, you must mark the material appropriately before cutting out the gasket. You can mark the gasket by laying the material over the flange and marking the cutting limits by light blows with a ball peen hammer. (This procedure should be used only for MARKING the gasket; do not cut the gasket completely by this procedure.)

You can also mark a gasket by chalking the face of the flange, laying the gasket material over the flange,' and applying pressure to the material. This will transfer the chalked impressions of the flange to the material. Gaskets may also be laid out using the procedure previously described for laying out a flange.

FLANGE MAKEUP.—Much of the trouble experienced with leaky joints in piping is due to poor alignment or improper allowance for expansion. Though you won't be able to correct expansion problems in existing piping, you can correct alignment

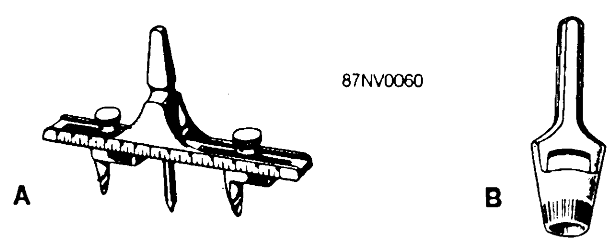


Figure 16-21.—Gasket cutter and gasket punch.

problems. Most piping systems have installed pipe hangers or supports that can be adjusted to properly support the pipe. Adjust the hangers by loosening up on the supports and then adjusting them to carry their share of the load. By adjusting pipe hangers and supports, you should be able to align piping sections so that flange bolts may be inserted freely without forcing.

Plain Flange Makeup.—This section will address the makeup of plain flanges using flexible gasket material. After you have aligned the flanges, choose the proper gasket material for the job at hand. When choosing gasket thickness, keep the following factors in mind:

- The thinner the gasket material the better the joint, especially in high-pressure joints.
- If the flanges are too far apart to be brought together, use a spacer and two thin gaskets (except for spiral wound, buna, and cork gaskets) rather than one that is thicker than l/16 inch.
- With the use of thinner gaskets, you may have to use stronger bolts to obtain required gasket compression.

After obtaining the correct gasket material, you should check the new gasket for brittleness and imperfections before installation. Replace bolts and nuts that show signs of corrosion, damage, or other imperfections. Before inserting the gasket between the flanges, you should coat one side of the gasket with graphite. By coating one side of the gasket with graphite, you will lessen the danger of tearing the gasket when the joint is broken. After installing the gasket, insert all the bolts and nuts and tighten as required.

Buna and Cork Gaskets.—These gaskets require special precautions when making up flanged joints. Buna and cork gaskets should be compressed between 20 and 30 percent of the original thickness but never more than 70 percent. If you compress the gasket more than 70 percent, you could cause excessive side flow, permanent set, or loss of resiliency. After you assemble a buna- or cork-gasketed joint, tighten setup nuts in approximately 180- and 90-degree sequence from the starting point. After final seating of the gasket, you should use feeler gauges at 90-degree intervals to measure gasket compression.

Raised Face Flange Makeup.—Raised face flanges are designed for use in high-pressure and temperature systems using spiral-wound metallic gaskets. Spiral-wound metallic gaskets are designed so that when the mating flanges are brought up against the outer metal ring, the gasket will not be crushed and an adequate preload is imparted on the gasket. After aligning the joint, inserting the gasket, and installing the bolts as previously discussed, you are ready to tighten the joint. Tighten the bolts in sequence according to the applicable technical documentation until you bring the flanges in contact with the gasket's outer ring. After flange contact is made, you should torque the bolts to the required tension. An alternate technique would be to measure the thickness of the outer ring of the gasket. You should then tighten the joint until the distance between the flanges is equal to the ring thickness plus 0.003 inch. Check this dimension with a feeler gauge at four points, 90 degrees apart. Remember to tighten all joints evenly and maintain proper alignment.

Bolt-Stud Stress.—To ensure that the gasket has been compressed the correct amount and that the bolt-stud has not been overstressed, measure the elongation of each bolt stud. The bolt-stud stress required for proper compression of gaskets is shown in table 16-3. These bolt-stud stresses have been selected to provide a reasonable factor of safety based on the yield point of the material and to ensure a tight joint.

Table 16-3.—Bolt-Stud Stress Required for Correct Compression of Metallic-Asbestos Spiral-Wound Gaskets

Type Gasket	Operating Pressure (psi)	Size of Pipe or Tubing	Bolt-Stud Stress (psi) (based on cross-sectional area at root diameter of thread)
MIL-G-16265	150	All	30,000 ± 10%
	300 400	l/4″ to 1″ IPS and 16″ OD	25,000 ± 10%
	600	1-1/4″ to 12″ IPS and 14″ to 15″ OD	30,000 ± 10%
MIL-G-21032	150 300 400 600 900 1500	1/4″ to 1″ IPS	25,000 ± 10%
		1-1/4″ IPS and larger	30,000 ± 10%
	2500	All	25,000 ± 10%

Table 16-4.—Approximate Torque Required to Obtain Bolt-Stud Stress of 25,000 psi and 30,000 psi in Various Sizes of Alloy Steel Bolts and Studs (UNC)

Nominal Size (inches) of Alloy Steel Bolt or Stud	Approximate Torque (foot-pounds) Required to Obtain 25,000 psi Stress	Approximate Torque (foot-pounds) Required to Obtain 30,000 psi Stress
1/2	25	30
5/8	50	60
314	83	100
718	133	160
1	205	245
1-M	295	355
1-1/4	416	500
1-3/8	567	645
1-1/2	667	800

The approximate torque required for bolt-stud stresses of 25,000 psi and 30,000 psi is shown in table 16-4.

These figures assume that the threads (UNC) are well lubricated. Torque wrenches should be used to apply the initial bolt-stud stress. The dial of the torque wrench indicates the torque (in foot-pounds) applied. The torque values given in table 16-4 should be applied to obtain the required stress.

Bolt-stud stress must be checked by measuring the bolt-stud elongation. This check ensures that the gasket has been compressed enough, and it prevents excessive compression of the gasket and overstressing of the bolt-stud.

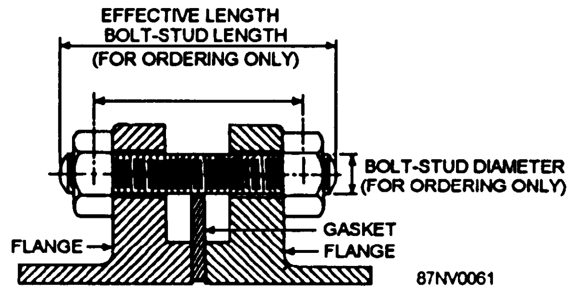


Figure 16-22.—Bolt-stud measurements.

Bolt-stud stress is checked by measuring the overall length of the bolt-stud before and after installation to determine the total amount of stretch (elongation). The total amount of stretch is then divided by the effective length of the bolt-stud to determine the stretch per inch of effective length.

The effective length of a bolt-stud is generally considered to be the distance from the center of one nut to the center of the other nut (fig. 16-22).

Naval shipyards and repair ships are equipped with strain gauges for measuring bolt-stud elongation. When strain gauges are not available, use the best micrometer calipers available. If you do not have micrometer calipers, use a C-frame, such as the one shown in figure 16-23.

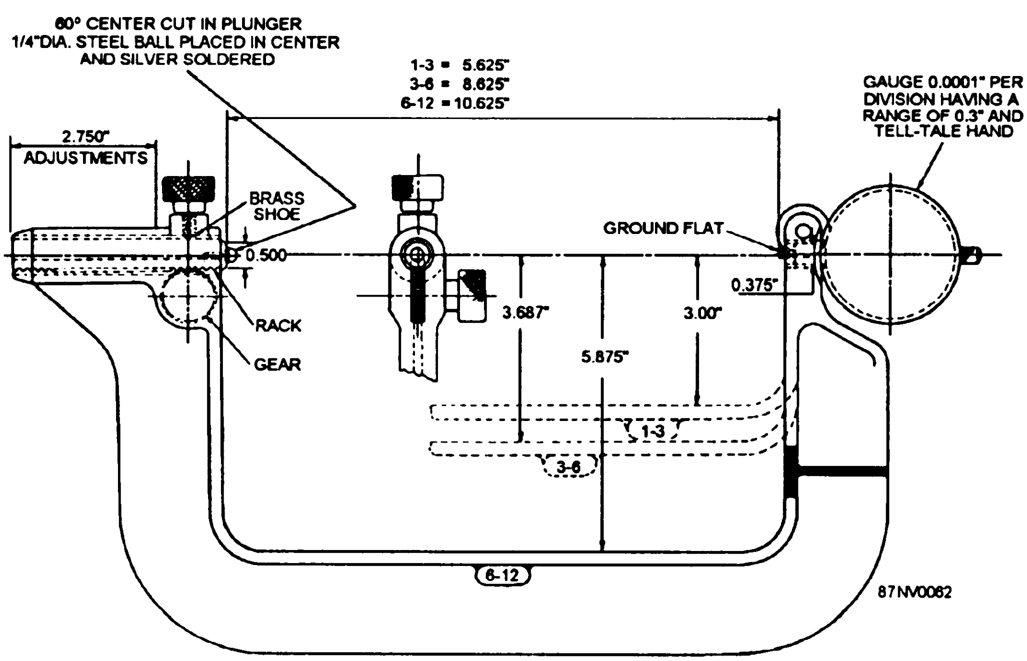


Figure 16-23.—C-frame gauge for measuring bolt-stud elongation.

Table 16-5.—Bolt-Stud Elongation Table

Stress (psi), based on cross-sectional area at root dieter of thread	Stretch (inches per inch of effective length)
1,000	0.000033
20,000	0.000660
25,000	0.000833
30,000	0.00100
40,000	0.001320
45,000	0.001485

The C-frame spans the bolts-studs, and the amount of elongation is measured with a dial micrometer. Table 16-5 is a bolt-stud elongation table.

The following example illustrates the use of tables 16-3, 16-4, and 16-5. Suppose you are required to make up a flanged joint in a 150-psi system. You are using a metallic-asbestos spiral-wound gasket of the type covered in specification MIL-G-16265, high-temperature alloy steel, and studs 1 inch in diameter with an effective length of 6 inches. Table 16-3 shows that the amount of stress required for proper compression of the gasket is 30,000 psi 10 percent. Table 16-4 tells you that approximately 245 foot-pounds of torque must be applied to obtain a stress of 30,000 psi in a l-inch alloy steel bolt or stud. From table 16-5, you find that the elongation of 30,000 psi should be 0.001 inch per inch of effective length. Since the effective length is 6 inches, the elongation of the stud when stressed to 30,000 psi should be 0.006 inch.

After applying 245 foot-pounds of torque with a torque wrench, check the elongation of the stud. If the elongation is 0.006 inch, then a 30,000 psi stress has been applied and the joint is properly sealed. If the elongation is less than 0.006 inch, increase the torque until the stud is elongated to 0.006 inch.

Cold Pull-up Joints.—Some flanged joints were originally assembled during the cold springing of the piping system. These joints are specified on ships' drawings. By remaking these joints first, you will avoid excessive misalignment of gasket seats. When remaking cold pull-up joints, install temporary pull-up bolts-studs and torque to specified tension. The purpose of installing temporary pull-up bolts-studs is to avoid damage to the threads of permanent bolts-studs. After cold pull-up is completed, replace temporary pull-up bolts one by one with permanent bolts-studs, and torque to proper tension.

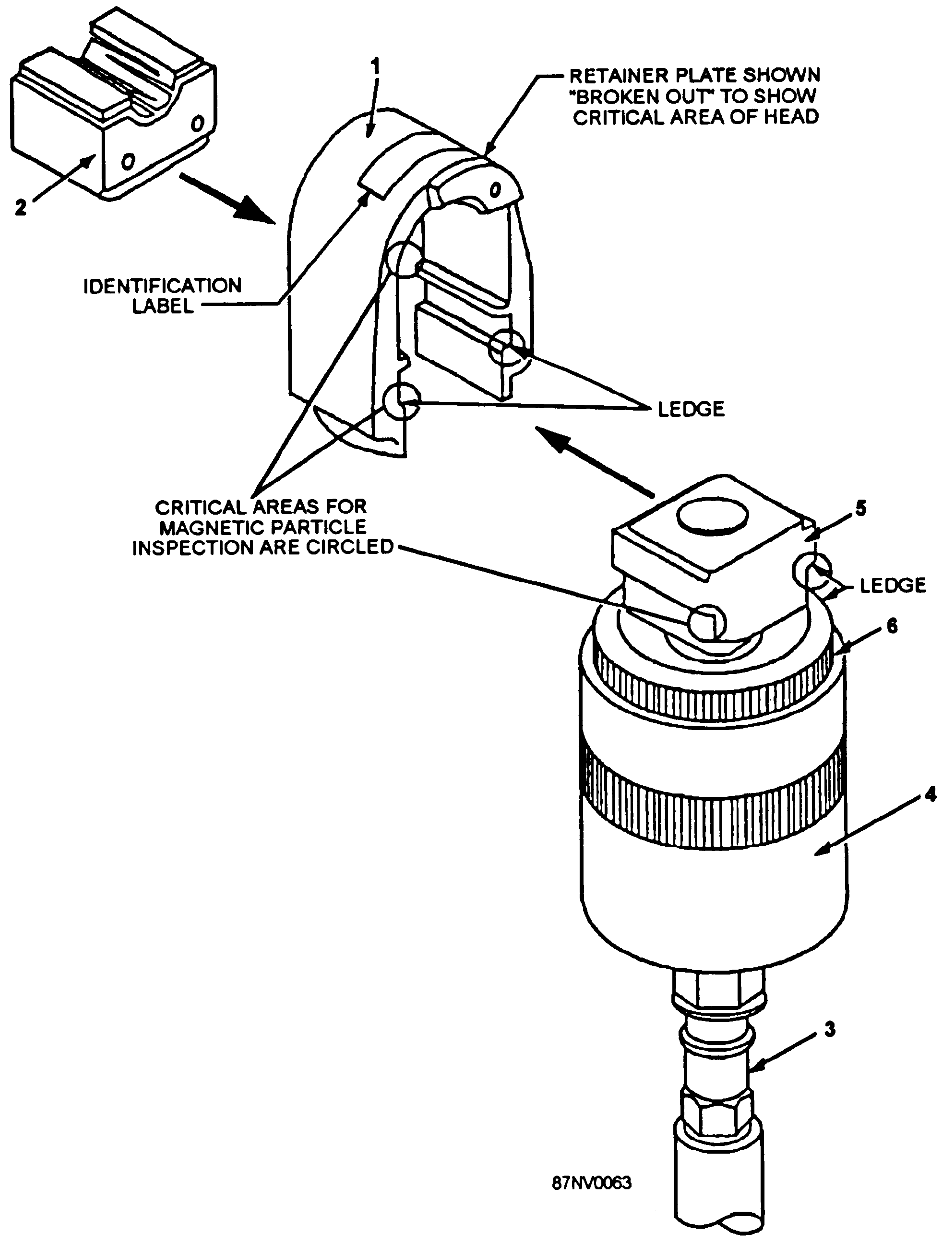
MARINE MECHANICAL PIPE FITTINGS

Swage maine fittings (SMF) and elastic strain preload (ESP) fittings are new processes that have been approved by NAVSEA for the mechanical joining of pipe and tubing. These two processes employ mechanical fittings vice welding and brazing to join pipe. They have several advantages over welding and brazing. They may be used when "hot work" is not allowed. It is a lightweight, portable, one person operation that greatly reduces the man-hour requirements of a job. The absence of flux, slag, or oxides eliminates the need to flush pipe interiors. SMFs and ESP fittings may be used on high-pressure, low-temperature systems. The following sections will discuss both of these methods in greater detail.

SWAGE MAINE FITTINGS

The tools used to install swage fittings are portable and require only one operator. The major tool is a hydraulic pump, which is normally air-powered. The pump drives an actuator that converts hydraulic pressure to linear travel and sufficient force to swage the fittings onto the pipe. Different die sets are used with the different types and sizes of fittings. Specific gauges are used to measure the pipe, locate fittings on the pipe, and ensure that the fitting has been swaged completely. The following equipment is necessary to install swage marine fittings:

- Power unit—Comes in 13-, 31-, 40-, 70-, and 100-ton units. Requires 5,500 to 10,000 psi of hydraulic pressure.
- Swage head assembly—Consists of a die holder assembly to hold the lower die half and the yoke assembly to hold the upper die half (fig. 16-24).
- Die set—Two dies. The halves contract radially when force is applied to the die holder assembly.
- Retention positioning sleeves—Used for 6,000-psi fittings in size 3/8 inch NPS and 3/4 inch OD tubing or above.
- Marking/inspection gauge—Used to verify the OD of pipe or tube, to locate installation and inspection marks, and to verify seal retention of after-swage dimensions.



1. Yoke assembly
2. Die holder assembly (with lower die half shown)
3. Pressure line to hydraulic power supply
4. Power unit
5. Strut
6. Knurled nut

Figure 16-24.—Swage tool component parts.

- Portable hydraulic power supply—Converts mechanical, electrical, or pneumatic energy to hydraulic energy.

Pipe Preparation

Pipe end preparation is improtant to ensure a good contact area between the pipe and and the elastomeric seal within the fitting. The SMF must be installed in a straight section of pipe with no wrinkles, bulges, or dents. If the pipe is galvanized, you should remove the galvanization with emery cloth until a smooth round surface is obtained. The pipe end should be cut no more than 3 degrees off square, but a cut of 5 degrees off square is acceptable. Apply a chamfer of l/16 inch at approximately 30 degrees of the cut end and deburr the inside of the pipe, using 120 or 150 grit aluminum-oxide cloth to remove surface defects.

Pipe Inspection and Insertion Marking

Using the proper marking/inspection gauge, verify the OD of the pipe and fitting as shown in figure 16-25. The P-MAX gauge must fit over the pipe/fitting in the region of the pipe/fitting contact; the P-MIN must not make three-point gauge contact or have two points 90 degrees apart. Check two places on the pipe 90 degrees apart for ovality. Refer to figure 16-26 for gauge usage.

After checking and verifying the pipe diameter and roundness, use the marking/inspection gauge to lay out the inspection and insertion marks. Refer to the manufacturer's technical manual for proper insertion depth. If the pipe wall thickness is greater than 0.125 inch, use a scriber to mark the pipe. For pipe wall thickness of less than 0.125 or stainless steel material use a chloride-free marking pen.

System Fit-up

After marking the pipe, you are ready to install the SMF. Apply a lubricant compatible with the system fluid to the pipe end and insert the pipe end into the fitting. Keep rotation and twisting to a minimum when inserting the pipe. A slight resistance should be encountered during insertion of the pipe into the fitting. If no resistance is encountered, recheck the pipe to the fitting match-up and the fitting for placement and damage of the elastomeric seal. Position the end of the fitting over the pipe installation mark so that some portion of the mark is visible. You must position the pipe in the fitting to ensure an acceptable joint (fig. 16-27).

Assemble the swage head assembly according to the manufacturer's directions and swage the fitting. After swaging, inspect the swage fitting dimensions according to the latest manufacturer's technical manual.

ELASTIC STRAIN PRELOAD (ESP) FITTINGS

ESP fittings provide the same advantage as the SMF. There are many similarities in installation procedures of the two fittings. However, the basic design of the ESP fittings is different from that of the SMF. The hydraulic pressure is applied in a horizontal position, as opposed to vertical. Their installation is limited to copper pipe, class 200 90/10 copper nickel pipe up to 2 l/2 inches nominal and 3 16 stainless steel l/4 inch schedule 80 pipe used in Halon systems. The following equipment is necessary to install ESP fittings:

- Locking power head—Consists of a stationary and a movable jaw assembly.
- Marking/inspection gauge—Used to verify the OD of pipe or tube, to locate installation and inspection marks, and to verify seal retention of after-swage dimensions.
- Portable hydraulic power supply—Converts mechanical, electrical, or pneumatic energy to hydraulic energy.

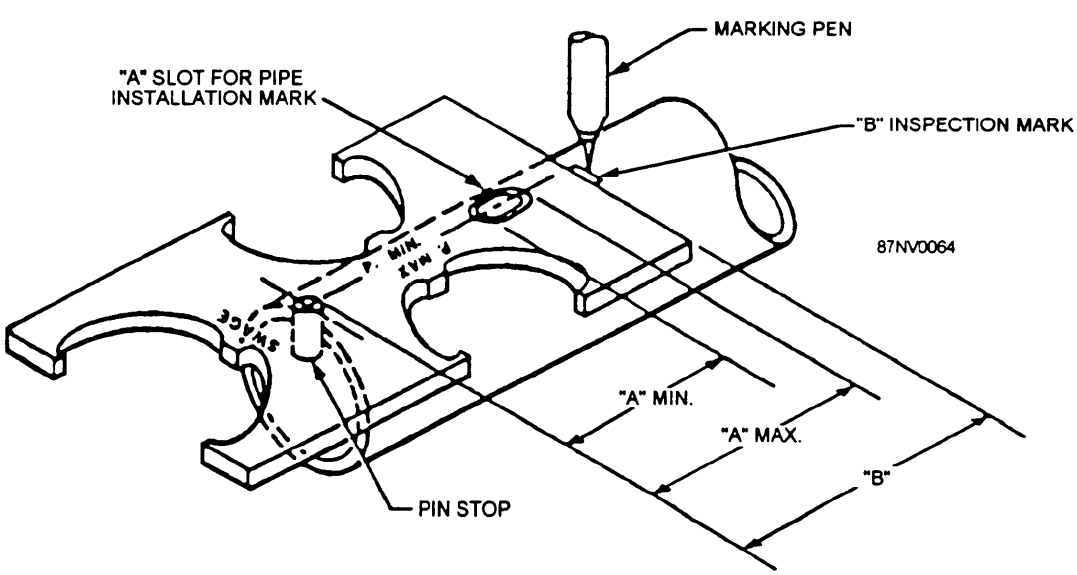


Figure 16-25.—Using marking/inspection gauge to mark pipe.

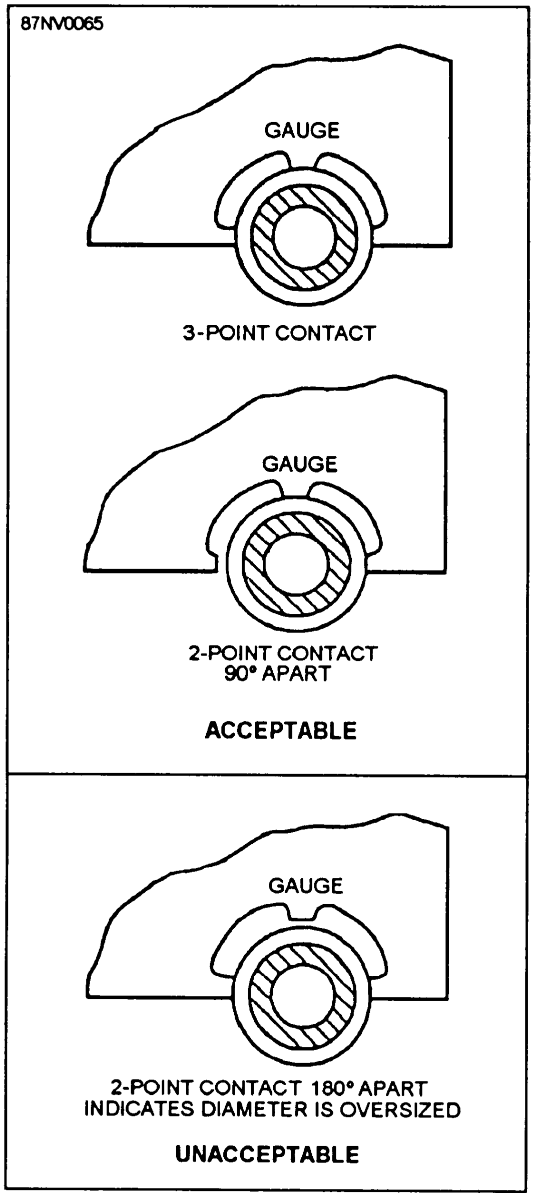


Figure 16-26.—Using marking/inspection gauge for pipe/tubing verification.

Pipe Preparation and Marking

The pipe is prepared in the same manner as previously discussed for SMFs. Use the multipurpose marking gauge (fig. 16-28) to verify the pipe end squareness and pipe outside diameters. Check the pipe diameters at two points 90 degrees apart to get true dimension readings. After obtaining acceptable pipe diameters, use an indelible marking pen to mark the installation and inspection markings.

Installation and Inspection

Installation of the ESP fittings is an easy and quick process. Slide the fitting onto one pipe end. It should slide easily over the pipe end. DO NOT FORCE the fitting over the pipe end because the sealing surface could be damaged or scratched. Align the fitting on the installation mark as shown in figure 16-29. Using the locking power head and following the manufacturer's instructions, lock the fitting onto the pipe. Remove the tool head and inspect the installation. The swage fitting should be checked for the following criteria (as shown in fig. 16-30).

- The swage ring should be seated against the fitting body tool.
- The inboard inspection marks should be partially covered by the fitting body.
- The fitting body should extend from underneath the ESP fitting.

If the fitting fails inspection, the joint should be cut out and replaced.

SHAPING TUBING AND PIPE

Bending is the shaping operation that you probably will use the most when working with tubing or pipe. Other shaping operations include flaring tube ends,

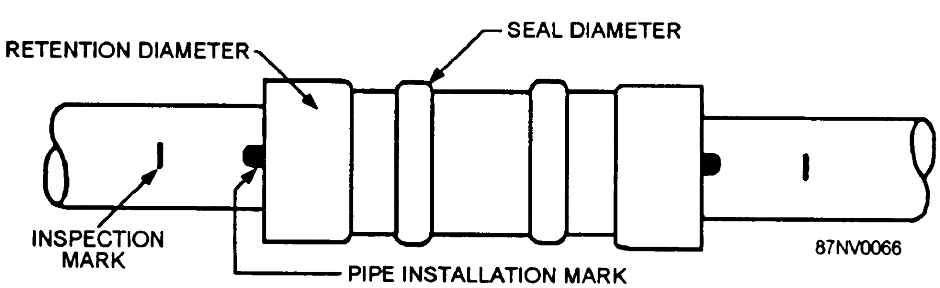


Figure 16-27.—Correct position of swage marine fitting for swaging.

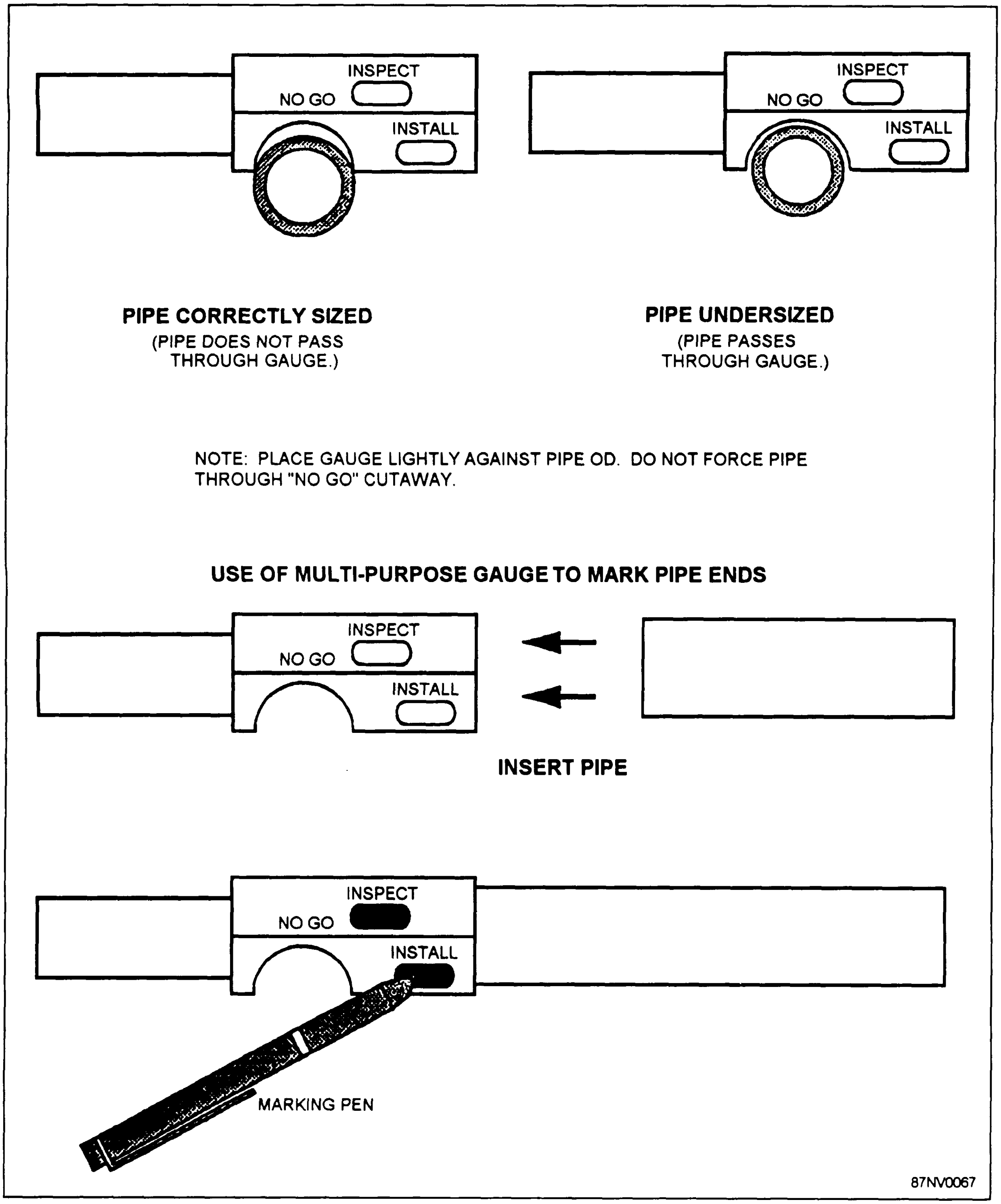


Figure 16-28.—Use of the multipurpose gauge.

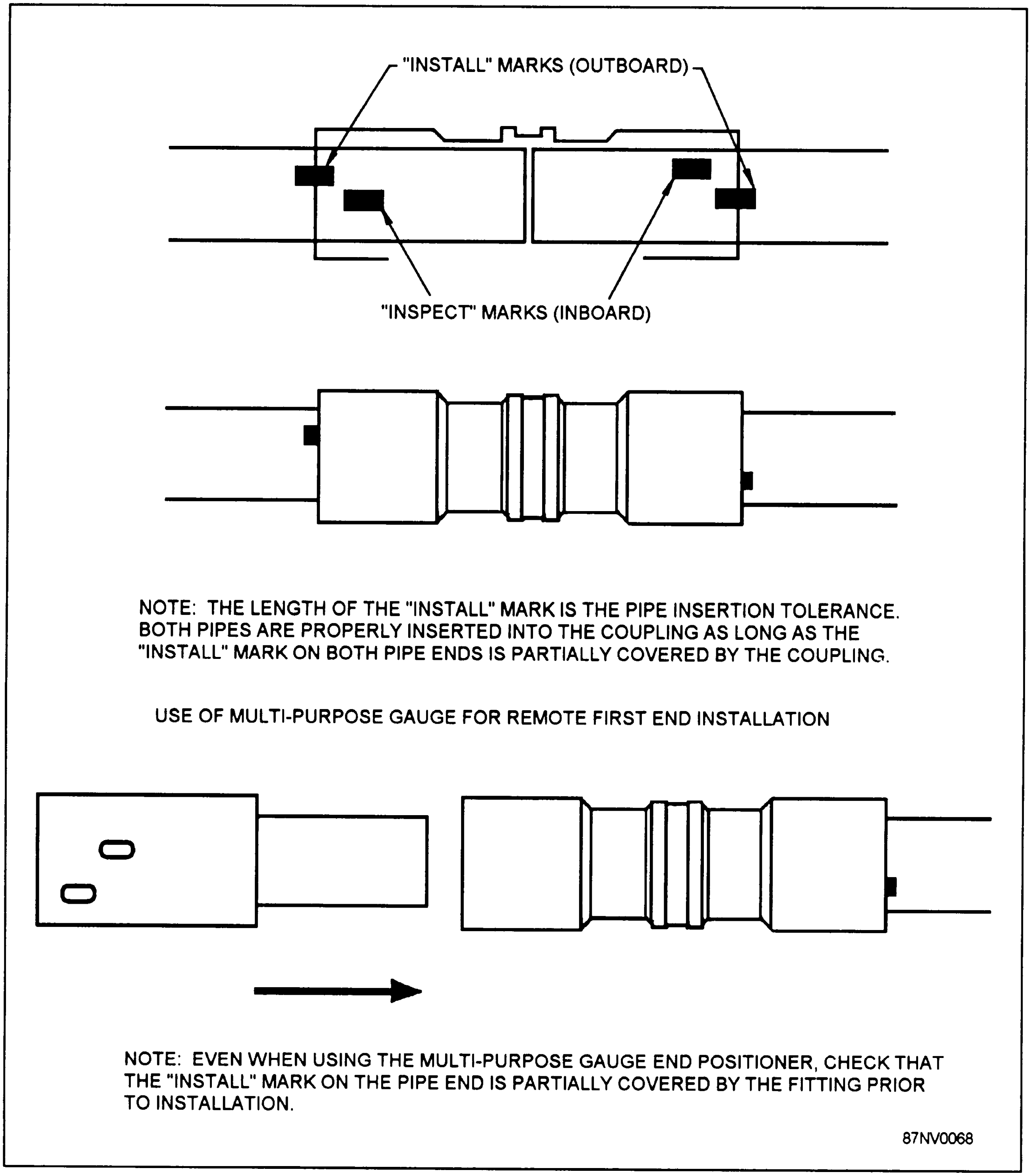


Figure 16-29.—Proper alignment and fit-up of pipe ends in the coupling.

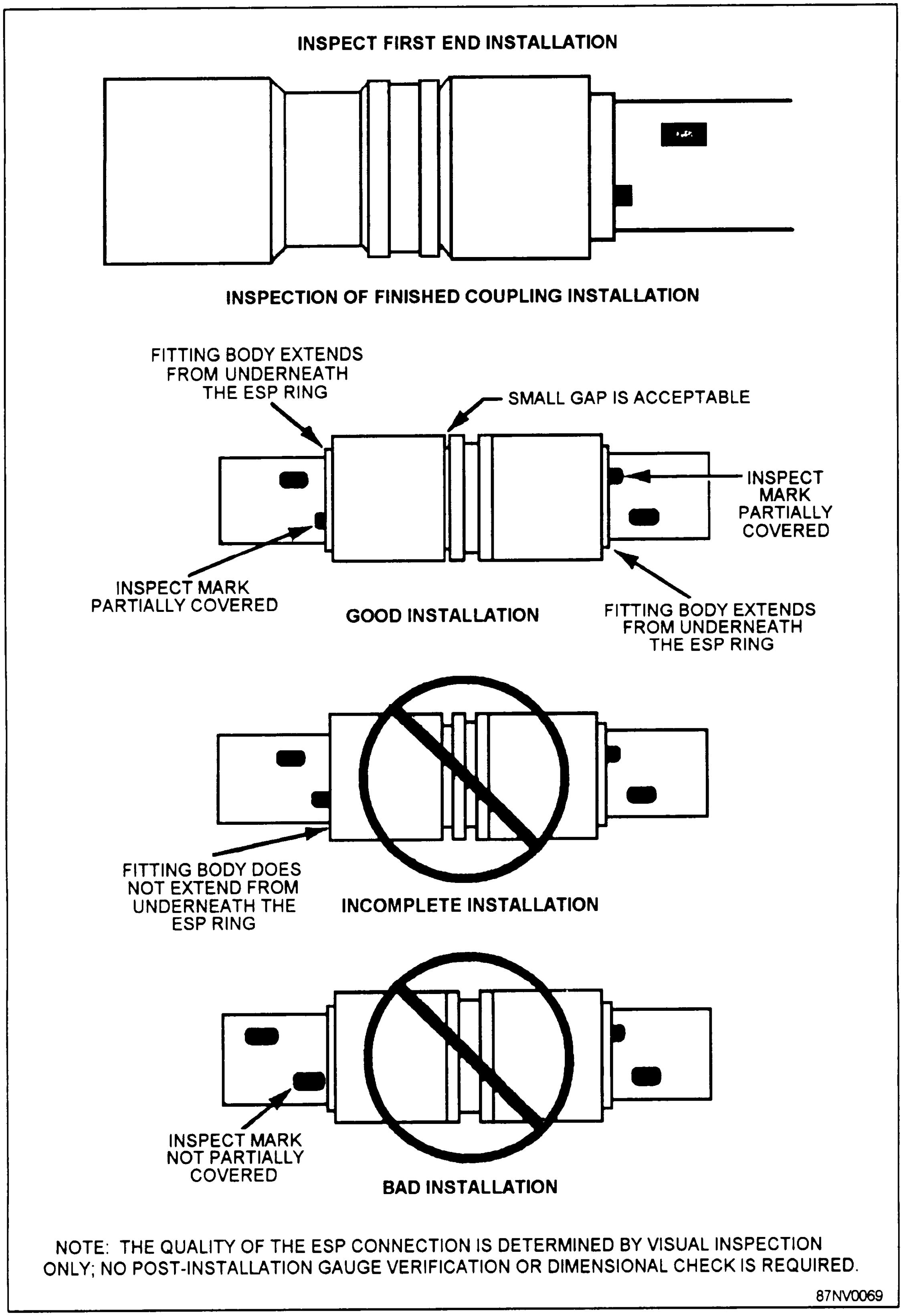


Figure 16-30.—Quality control inspection.

reducing tube ends, sizing tube ends, and joining tube ends.

BENDING TUBING AND PIPE

Tubing and pipe can be bent by the methods described earlier in this chapter. Your main problem will be to prevent wrinkles and flat spots. Wrinkles are caused by compression of the pipe wall at the throat (inside) of the bend. Flat spots are caused by lack of support for the pipe wall, by stretch in the heel (outside) of the bend, or by improper heating.

If the pipe is properly packed and properly heated, you can prevent wrinkles and flat spots. You can do this by bending the pipe in segments so that the stretch is spread evenly over the whole bend area. When a pipe is bent, the stretch tends to occur at the middle of the bend. If the bend area is divided into a number of segments and then bent in segments, the stretch will occur at the center of each segment. Therefore, the stretch will be spread fairly evenly over the whole bend area. Another advantage of bending in segments is that this is about the only way you can follow a wire template accurately.

Use the following procedure to make a segmented 90-degree cold bend in copper-nickel tubing:

1. Lay out the bend area from the wire template.

2. Divide the bend area into a number of segments, as shown in figure 16-31. Remember, the more segments you use, the smoother the bend will be. The number of segments that will work best in any particular case will depend on the size (diameter) and wall thickness of the tubing, the degree of the bend, and other factors that you will learn on the job.

3. Bend each segment slightly. Bend the last two or three segments less than the others to allow for adjustments.

4. Check the bend with the wire template.

5. Starting at the first segment again, bend each segment to a slightly greater angle than you did the first time.

6. Check the tubing again with the wire template.

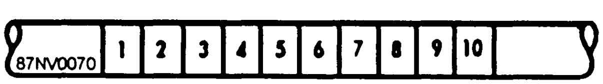


Figure 16-31.—Layout for bending tubing in segments.

7. As you bend the segments, you will probably have to move the template out of the way. Be sure to keep it on the centerline of the piping when you move it.

8. Continue bending the segments and check the tubing with the template until the tubing has been bent to the angle of the template.

You can also use the segment method of bending to make hot bends in sand-filled pipe. Suppose, for example, that you need to bend a piece of copper tubing to a 180-degree bend and then to a 90-degree bend, as shown in figure 16-32. Treat the total bending operation as though it consisted of three separate 90-degree bends, and follow this procedure:

1. Properly pack the tube with sand and use the wire template to lay out the bend area of the first bend. Do NOT mark the area of the second bend until the first bend has been made; some stretch will occur when the first bend is made. Also, the third bend area cannot be laid out until after the first and second bends have been made.

2. Divide the first bend area into four segments and mark them as shown in figure 16-33. Use chalk or soapstone to mark the numbers.

3. Place a baffle behind the first segment and heat the segment to a full red.

4. Apply pressure and bend the first segment about one-fourth of the required amount (about 22 1/2°).

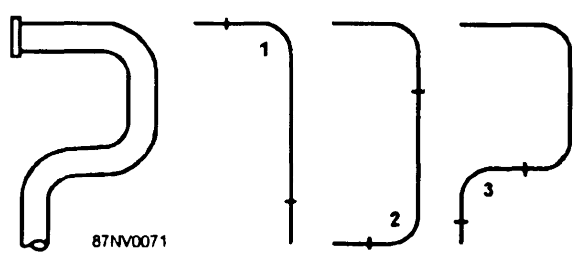


Figure 16-32.—Tubing bent to 180° and then to 90°.

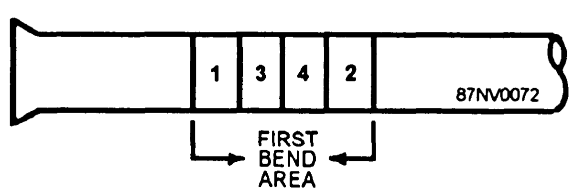


Figure 16-33.—Layout for first 90-degree bend.

5. Move the baffle to the second segment. Heat the second segment while the first segment is cooling.

6. When the second segment has been heated to a full red, bend it approximately the same number of degrees that you bent the first segment. Do NOT bend the second segment until the first one has cooled. If the first one is still hot, it will also bend when you bend the second segment.

7. Repeat these steps for the remaining segments.

After you have made the first 90-degree bend, lay out the second bend area and divide it into four segments. Starting with the first segment, repeat the bending process described for making the first bend. After all four segments have been bent and the second bend checks with the template, the return bend is complete.

The last 90-degree bend is laid out as shown for the preceeding bend. Bend the tubing in segments in the same way that the first two bends were made.

Various types of hand tools are available to make bends in small copper tubing. One commonly used type of hand tube bender is shown in figure 16-34, together with the steps for using the bender.

One very simple device for bending small tubing is nothing more than a coil spring. It is slipped over the tubing and centered at the middle of the bend area. To make the bend, you merely grasp the coil spring in both hands and bend the tubing as far as necessary. The effect of this type of bender is to divide the bend area into a large number of segments. The finished bend is smooth, without sharp creases or collapsed areas. A similar device is available for inserting inside copper tubing that is to be bent. The internal spring bender can be used to bend tubing that is already flared at both ends. It can also be used for other bending work where the external spring bender would not be feasible. Both internal and external coil spring benders are available in a number of different sizes to fit different sizes of tubing.

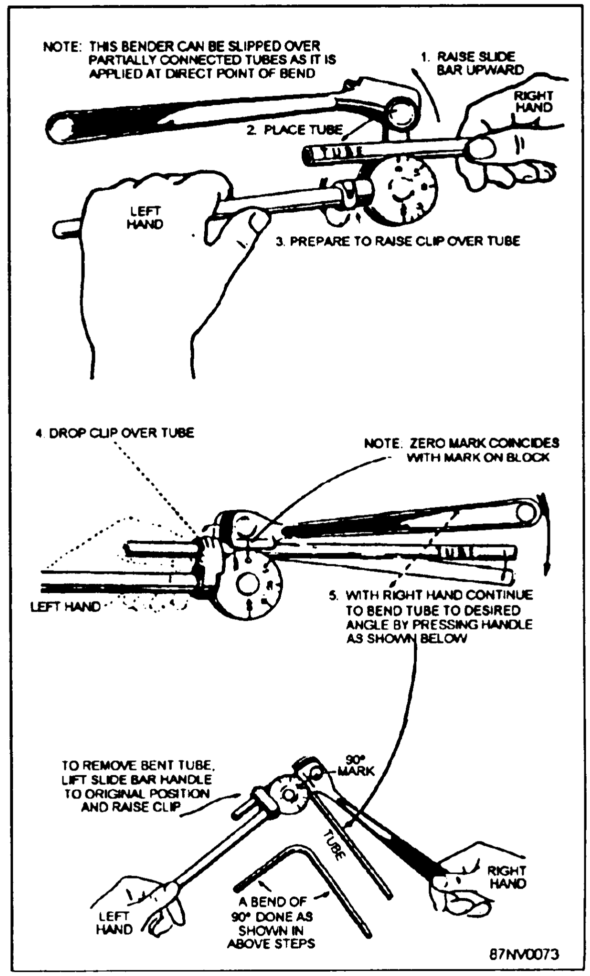


Figure 16-34.—Hand tube bender.

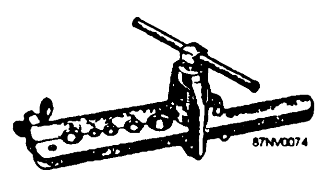


Figure 16-35.—Hand flaring tool.

FLARING TUBING

Flaring, often called belling, is done by stretching the end of the tube into a funnel shape that can be held by a fitting. If both ends of the tube are to be flared, be sure to slip all necessary fittings over the tube before you flare the second end. After both ends have been flared, the fittings will not go on the tubing.

Tubing can be flared in several ways. If special flaring tools are not available, you can put the tubing on a stake or mandrel and shape it with hammers or mallets.

An easier way to flare copper tubing is to use a hand flaring tool of the type shown in figure 16-35. The procedure is as follows:

1. Check to be sure that the tubing has been cut off squarely and evenly. Remove all burrs from inside and outside the tubing.

2. Open the flaring tool so that you can insert the tubing in the opening of the correct size. Most hand flaring tools have openings of several different diameters to accommodate different sizes of tubing.

3. Insert the end of the tubing so that it extends a short distance above the surface of the flaring block. The distance that the tubing must extend above the block is different for different diameters of tubing.

4. When the tubing is in the proper hole and extends the required distance above the surface of the flaring block, close the flaring tool. Now tighten the block by turning the wing nut.

5. Place the yoke over the end of the tubing and tighten the handle of the yoke. This forces the flaring pin into the end of the tubing.

The completed flare must be square and true at the end and it must be the right length. Figure 16-36 shows three mistakes that are commonly made in flaring tubing.

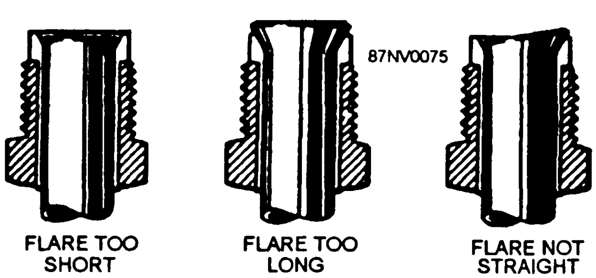


Figure 16-36.—Examples of incorrect flares.

SIZING TUBING AND PIPE

Tests have shown that if optimum strength is to be achieved between pipes and fittings, correct clearances must be obtained. This is particularly important when preparing silver-brazed joints. Sometimes the ends become enlarged when the pipe or tubing is bent. Other operations may cause the ends to become considerably smaller. In either case, the dimensions must be corrected to obtain proper fit between the tubing and the fitting. Pipe expanding tools (figs. 16-37 and 16-38) are designed to correct out-of-roundness and expand pipe ends to correct clearances. These tools are manufactured in sizes to fit most standard size pipes.

Pipe Sizing Machine

Pipe sizing machines (expanders) use a series of hardened rollers that are forced against the pipe wall by a mandrel and thrust nut (fig. 16-37). By rotating the mandrel, the rollers revolve around the inside of the pipe to bring the pipe into roundness. These types of machines may be used on all types of piping material.

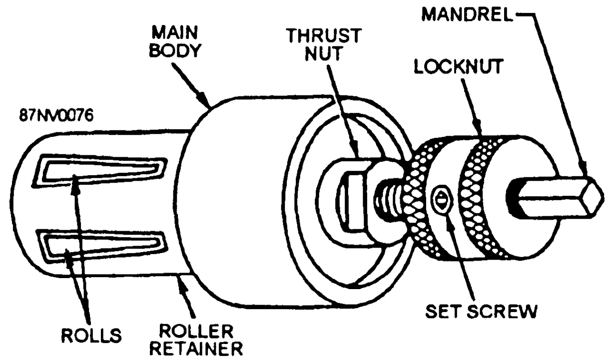
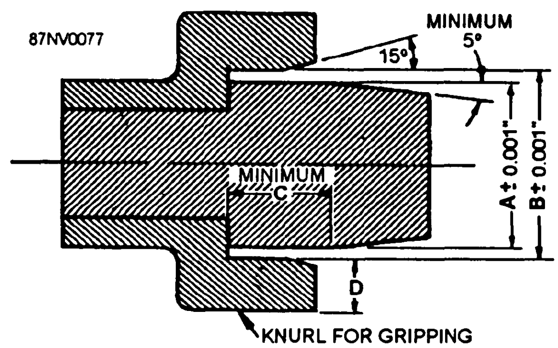


Figure 16-37.—Pipe sizing machine.



FITTING SIZE (INCHES)	DIMENSIONS			
	A	B	C	D
1/4	0.400	0.500	33/64	1/4
3/8	0.535	0.675	9/16	1/4
1/2	0.700	0.840	5/8	1/4
3/4	0.910	1.050	21/32	1/4
1	1.175	1.315	11/16	3/8
1 1/4	1.520	1.660	3/4	3/8
1 1/2	1.760	1.900	7/8	7/16
2	2.235	2.375	27/32	1/2

Figure 16-38.—Shaping and sizing tool.

If the pipe needs to be expanded, you must first determine the amount of expansion required. This is done simply by subtracting the OD of the pipe from the inside diameter (ID) of the fitting. In braze joints, you may be required to expand pipe to within 0.005 inch of the fitting.

After the pipe is cut and the pipe end deburred, simply insert the roller body into the pipe end. Back off the locknut and rotate the mandrel until the rollers contact the wall of the pipe. You may need to hold the thrust nut with a wrench while turning the mandrel to keep it from rotating until the rollers contact the pipe wall. Adjust the locknut until it seats against the thrust nut and tighten the setscrew. Rotate the mandrel several turns to round out the pipe, then remeasure the clearance between the fitting and pipe. If further expansion is required, back off the locknut one or more turns and tighten the setscrew. The amount of expansion for one turn of the locknut is usually stamped on the locknut. As you rotate the mandrel, the rollers will automatically be expanded by the mandrel and thrust nut until the locknut seats against the thrust nut. Repeat the process until proper diametrical clearance is obtained.

Drift Pins or Plugs

Pipe or tubing may also be expanded using a drift pin or plug of hardened, ground, and polished tool steel (fig. 16-38). They are usually made on site to a specific dimension and cannot be adjusted. They are simply driven into the pipe end, causing the pipe to be rounded and expanded. Pins and plugs can only be used on pipe up to 2 inches in diameter.

Pipe Sizing Restrictions

If the diametrical clearance between the fitting and pipe must be reduced, do so by filing the pipe wall. If the pipe end is expanded, the maximum diametrical expansion allowable is 0.060 inch. The maximum allowable diametrical expansion may be increased to 0.120 inch if the expanded pipe surface is checked for cracks after sizing using a dye penetrant inspection. If pipe sizing evolutions are performed, ensure that the pipe wall in the sized area does not fall below minimum wall thickness.

JOINING TUBING AND PIPE

You can join tubing and pipe by threading, silver brazing, braze welding, or by gas shielded-arc welding. Welded and silver-brazed joints are most commonly used. Use threaded joints only when (1) the tubing or pipe is hard enough to be threaded, (2) the wall thickness is thick enough to allow satisfactory threading, and (3) threaded joints are permitted in the system for which the tubing or pipe is to be used. Threaded joints are not permitted in many shipboard piping systems.

Tubing or pipe must be thoroughly cleaned before it is joined. You can use acids to clean copper, but all traces of the acids must be removed from the work.

Making a Cup Joint

You can often use cup joints to join the ends of copper pipes or tubes that do not ordinarily need to be taken down. Pipes under 5 inches in diameter should have a cup length about equal to the pipe diameter. Cups for larger pipe are usually smaller in relation to the pipe diameter.

NOTE: These types of joints may only be used where authorized by competent authority.

Figure 16-39 shows a cup joint that is used to join the ends of two lengths of copper pipe. The cup is made at the end of one piece of pipe. The end of the other piece fits down into the cup. The cup must always be made in such a way that there will be the least possible interference with the flow of fluid in the system.

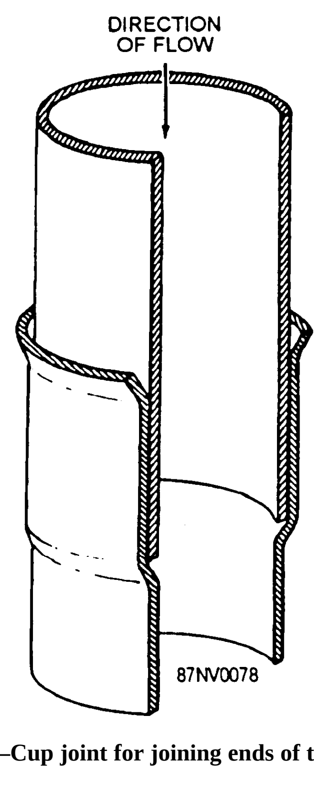


Figure 16-39.—Cup joint for joining ends of two copper pipes.

The pipe end in which the cup is to be made must be annealed before the work is begun and annealed frequently as it is worked. To form the cup, lay the annealed pipe on a grooved wooden block. Insert a round steel bar in the pipe. The outside diameter of the bar should be about 0.003 inch greater than the outside diameter of the inner pipe. Hold the bar firmly against the pipe, with the inserted end of the bar exactly at the place where the cup is to begin. Then hammer the steel bar. Revolve the pipe slightly and hammer the steel bar again. Continue to revolve the pipe and hammer the steel bar until the cup is formed. Stop whenever necessary to anneal the pipe end.

When the cup has been formed so that the inside pipe will fit into the cup, flare the end of the cup slightly. Then anneal and clean the cupped end of the pipe. Immediately after cleaning, apply flux evenly to each joint surface to be brazed.

After the two pipes have been fitted together, caulk the bottom edge of the cup tight against the inside pipe (fig. 16-39). Then braze the joint.

Making a Cup Branch

You will often use a cup branch to fit a branch line into a main line. One procedure for making a cup branch is shown in figure 16-40. First, drill a small hole in the main line pipe at the center of the intersection.

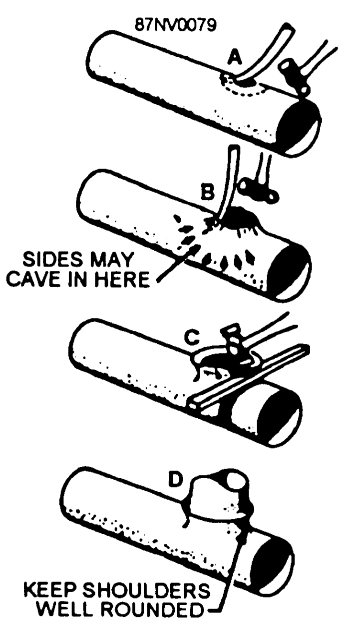


Figure 16-40.—Steps in making a cup branch.

Anneal the area of the pipe that is to be formed. Then, while the metal is still red hot, work the edge up with a raising bar, as shown in view A of figure 16-40. The sides may tend to cave in, as shown in view B. They can be bumped out with a bumping ball.

Shape the cup by the method shown in view C of figure 16-40 until it fits snugly around the end of the branch. Then peen the end of the branch to fit the contour of the cup. Flux and braze the joint. If necessary, peen the inside to ensure a smooth surface that will not interfere with the flow of fluid in the system.

MAINTENANCE AND REPAIR OF VALVES

Preventive maintenance is the best way to extend the service life of valves and fittings. As soon as you observe a leak, determine the cause, then apply the proper corrective maintenance. Maintenance may be as simple as tightening a packing nut or gland. A leaking flange joint may need only to have the bolts tightened or to have a new gasket or O-ring inserted. Dirt and scale, if allowed to collect, can ultimately cause leakage. Loose hangers permit sections of a line to sag, and the weight of the pipe and the fluids in these sagging sections may strain joints to the point of leakage. Always refer to the applicable PMS procedures and the *Navy Standard Valve Technical Manual.* When making valve repairs on more sophisticated valve types, you should refer to the manufacturer's technical manual.

Whenever you install a valve, be sure you know the function the valve is to perform; that is, whether it must prevent back flow, begin flow, stop flow, regulate flow, or regulate pressure. Inspect the valve body for information that is stamped on it by the manufacturer: type of system (oil, water, or gas), operating pressure, direction of flow, and other information.

You should also know the operating characteristics of the valve, the type of metal from which it is made, and the type of end connection it has. Operating characteristics and the type of material are factors that affect the length and kind of service that a valve will give. End connections indicate whether or not a particular valve is suited for installation in the system.

Valves should be installed in accessible places and with enough headroom to allow for full operation. Install valves with the stem pointing upward, if possible. A stem position between straight up and horizontal is acceptable, but avoid the inverted position (stem pointing downward). If the valve is installed with the stem pointed downward, sediments will collect in the bonnet and score the stem. Also, when a line is subjected to freezing temperatures, liquid trapped in the valve bonnet may freeze and rupture it.

Valves that have been in constant service over a long period of time will eventually require gland tightening, repacking, or a complete overhaul of all parts. If a valve is not doing the job for which it is intended, it should be dismantled and all parts inspected for corrosion, scarring, and erosion of seating surface and valve body. All defective parts must be repaired or replaced.

GLOBE VALVE

The repair of globe valves (other than routine renewal of packing) is generally limited to refinishing the seat and disk surfaces.

When refinishing the valve seat, do not remove any more material than is necessary. Valves that do not have replaceable valve seats can be refinished only a limited number of times.

Before you begin any repair work on the seat and disk of a globe valve, check the valve disk to make certain it is secured rigidly to and is square on the valve stem. Also, check to be sure the stem is straight. If the stem is not straight, the valve disk cannot seat properly. Carefully inspect the valve seat and valve disk for evidence of wear, for cuts on the seating area, and for improper fit of the disk to the seat. Even if the disk and the seat appear to be in good condition, they should be spotted-in to find out whether they actually are in good condition.

Spotting-in Valves

The method used to visually determine whether the seat and the disk of a valve make good contact with each other is called spotting-in. To spot-in a valve seat, first apply a thin coating of prussian blue evenly over the entire machined face surface of the disk. Then insert the disk into the valve and rotate it a quarter turn, using light downward pressure. The prussian blue will adhere to the valve seat at those points where the disk makes contact. Figure 16-41 shows what correct and imperfect seats look like when they are spotted-in.

After you have noted the condition of the seat surface, wipe all the prussian blue off the disk face surface. Apply a thin, even coat of prussian blue to the contact face of the seat. Again place the disk on the valve seat and rotate the disk a quarter of a turn. Examine the blue ring on the valve disk. The ring should be unbroken and of uniform width. If the blue ring is broken in any way, the disk is not making a proper fit.

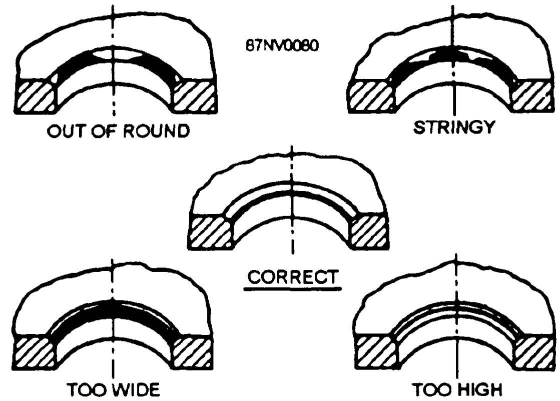


Figure 16-41.—Examples of spotted-in valve seats.

Grinding-in Valves

The manual process used to remove small irregularities by grinding together the contact surfaces of the seat and disk is called grinding-in. Grinding-in should not be confused with refacing processes in which lathes, valve reseating machines, or power grinders are used to recondition the seating surfaces.

To grind-in a valve, first apply a small amount of grinding compound to the face of the disk. Then insert the disk into the valve and rotate the disk back and forth about a quarter of a turn. Shift the disk-seat relationship from time to time so that the disk will be moved gradually, in increments, through several rotations. During the grinding-in process, the grinding compound will gradually be displaced from between the seat and disk surfaces. Therefore, you must stop every minute or so to replenish the compound. When you do this, wipe both the seat and the disk clean before applying the new compound to the disk face.

When it appears that the irregularities have been removed, spot-in the disk to the seat in the manner previously described.

Grinding-in is also used to follow up all machining work on the valve seats of disks. When the valve seat and disk are first spotted-in after they have been machined, the seat contact will be very narrow and will be located close to the bore. Grinding-in, using finer and finer compounds as the work progresses, causes the seat contact to become broader. The contact area should be a perfect ring covering approximately one-third of the seating surface.

Do not overgrind a valve seat or disk. Overgrinding tends to produce a groove in the seating surface of the disk. It also tends to round off the straight, angular surface of the disk. Machining is the only process by which overgrinding can be corrected.

Lapping Valves

When a valve seat contains irregularities that are slightly larger than can be satisfactorily removed by grinding-in, you can remove them by lapping. A cast-iron tool of exactly the same size and shape as the valve disk is used to true the valve seat surface. Two lapping tools are shown in figure 16-42.

Observe the following operating instructions when you use a lapping tool:

- Do not bear down heavily on the handle of the lapping tool.
- Do not bear sideways on the handle of the lapping tool.
- Rotate the lapping tool so that the lap will gradually and uniformly cover the entire seat.
- Keep a check on the working surface of the lapping tool. If a groove develops, have the tool refaced.
- Always use clean compound for lapping.
- Replace the compound frequently.
- Spread the compound evenly and lightly.
- Do not lap more than is necessary to produce a smooth, even seat.
- Always use a fine grinding compound to finish the lapping job.
- Upon completion of the lapping job, spot-in and grind-in the disk to the seat.

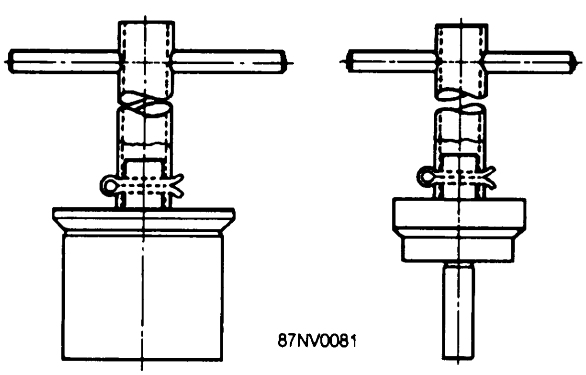


Figure 16-42.—Lapping tools.

Use only approved abrasive compounds to recondition valve seats and disks. Compounds for lapping and grinding valve disks and seats are supplied in various grades. A coarse grade compound is used when extensive corrosion or deep cuts are found on the disks and seats. A compound of medium grade is used to follow up the coarse grade; it may also be used to start the reconditioning process on valves that are not too severely damaged. A fine grade compound should be used when the reconditioning process nears completion. A microscopic-fine grade should be used for finish lapping and for all grinding-in.

Refacing Valves

Badly scored valve seats must be refaced in a lathe, with a power grinder, or with a valve reseating machine. However, the lathe rather than the reseating machine should be used to reface all valve disks and all hard-surfaced valve seats. Work that must be done on a lathe or with a power grinder should be turned over to machine shop personnel This discussion applies only to refacing seats with a reseating machine.

To reface a seat with a reseating machine (fig. 16-43), attach the correct 45-degree facing cutter to the

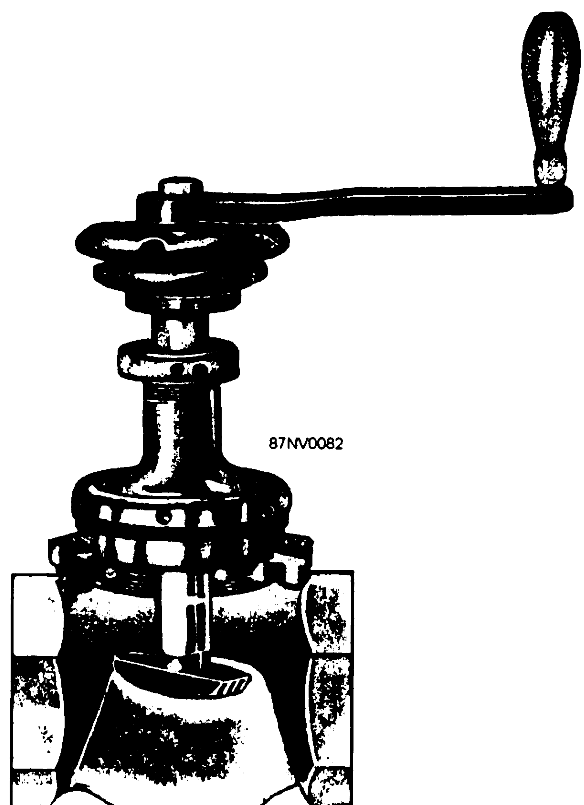


Figure 16-43.—Valve reseating machine.

reseating machine. With a fine file, remove all high spots on the surface of the flange upon which the chuck jaws must fit. Note that a valve reseating machine can be used ONLY with a valve in which the inside of the bonnet flange is bored true with the valve seat. If this condition does not exist, the valve must be reseated in a lathe, and the inside flange bored true.

Before placing the chuck in the valve opening, open the jaws of the chuck wide enough to rest on the flange of the opening. Tighten the jaws lightly so that the chuck securely grips the sides of the valve opening. Tap the chuck down with a wooden mallet until the jaws rest firmly and squarely on the flange. Then tighten the jaws further.

Adjust and lock the machine spindle in the cutting position and start the cutting by turning slowly on the crank. Feed the cutter slowly so that very light shavings are taken. After some experience, you will be able to know by the feel whether or not the tool is cutting evenly all around. Remove the chuck to see if enough metal has been removed.

Be sure the seat is perfect. Then remove the 45-degree cutter and face off the top part of the seat with a flat cutter. Dress the seat down to the proper dimensions, as follows:

Width of Seat	Size of Valve
1/16 inch	1/4 to 1 inch
3/32 inch	1 1/4 to 2 inches
1/8 inch	2 1/2 to 4 inches
3/16 inch	4 1/2 to 6 inches

After the refacing, grind-in the seat and disk. Spot-in as necessary to check the work. A rough method of spotting-in is to place pencil marks at intervals of about one-half inch on the bearing surface of the seat or disk. Then place the disk on the seat and rotate the disk about a quarter of a turn. If the pencil marks in the seating area rub off, the seating is considered satisfactory.

Repacking Valve Stuffing Boxes

If the stem of a globe valve is in good condition, stuffing box leaks can usually be stopped by setting up on the gland. If this does not stop the leakage, repack the stuffing box. The gland must not be set up or packed so tightly that the stem binds. If the leak persists, a bent or scored valve stem may be the cause of the trouble.

Coils (string) and rings are the common forms of packing used in valves. The form to be used in a particular valve will be determined, in part, by the size of the packing required. In general, rings are used in valves that require packing larger than one-fourth inch. When a smaller size is required, string packing is generally used.

When you repack a valve stuffing box, place successive turns of the packing material around the valve stem. When strong packing is used, coil it around the valve stem. Bevel off the ends to make a smooth seating for the bottom of the gland. Then put on the gland and set it up by tightening the bonnet nut or the gland bolts and nuts. To prevent the strong packing from folding back when the gland is tightened, wind the packing in the direction in which the gland nut is to be turned. Usually, where successive rings are used, the gaps in the different rings should be staggered.

Gate, globe, angle, and stop check valves are made to back seat the stem against the valve bonnet when the valve is fully opened. Back seating of these valves is a safety feature to eliminate the possibility of the stem being forced out under pressure while the valve is fully opened. Back seating makes possible the repacking of the stem stuffing box under pressure. However, you should attempt this only in emergencies and with extreme caution.

GATE VALVES

The manner in which a gate valve is used has a great deal to do with its service life. Gate valves should always be used either wide open or fully closed; never in a partially opened position. When a gate valve is partly open, the gate is not held securely, but swings back and forth with the pulsation of the flow. As the gate swings, it strikes the valve body and the finished surfaces, nicking and scoring them. When these surfaces are imperfect, the valve gate cannot set accurately and seal off the flow. A gate valve should never be installed in any position where a throttling or flow-regulating valve is required. A globe valve should be used in those situations.

Lapping is the best way to correct gate valve defects such as light pitting or scoring and imperfect seat contact. The lapping process is basically the same for gate valves as it is for globe valves. The exception is that the lap is turned by a handle that extends through the end of the valve body. Remove the valve from the system. Insert the lapping tool, without its handle, into the valve so that it covers one of the seat rings. Then attach the handle to the lap and begin the lapping. The wedge gate can be lapped to a true surface, using the same lap that is used on the seat rings. (**CAUTION:** DO NOT use the gate as a lap.)

Do not remove any more material than is necessary. You can resurface a gate valve only a limited number of times. By removing too much material, you will reduce the number of times the surface can be refinished and the life of the valve.

Leakage around the stem of a gate valve is caused by troubles similar to those in leaking globe valves. The same procedure is used to stop these leaks in both valves.

CHECK VALVES

Leaks are the principal trouble found in check valves. Leakage is caused by a pitted disk or valve seat. Pitting is usually caused by abrasives caught between the disk and the seat.

When a check valve requires maintenance because of pitting, the work will depend upon the type of disk in the valve. With a ball-type disk, you will have to replace the ball and grind the seat. A flat or conical disk can be repaired by grinding in the disk to its seat with a fine grinding compound.

Remember that fluid will flow through them in only one direction. Be sure they are installed correctly.

FLUSH VALVES

Any flush valve will give years of adequate and trouble-free operation if it is properly maintained. However, there are two major problems that may occur in flush valves: (1) the valve may run continuously instead of shutting off at the right time, or (2) the valve may fail to deliver the desired amount of water (short flushing). Both of these defects can waste a lot of water. One of the reasons for a flush valve is to reduce water waste; therefore, proper maintenance is important. Once you understand the principle and the operation of a valve, you will know what to look for when anything goes wrong. The internal working parts of a typical piston-type flushing valve are shown in figure 16-44.

Continuous flow through a piston-type flush valve is almost always caused by one of two things. Either the relief valve fails to seat properly, or the bypass valve is corroded. In both cases, there is not enough force on the piston to seat it.

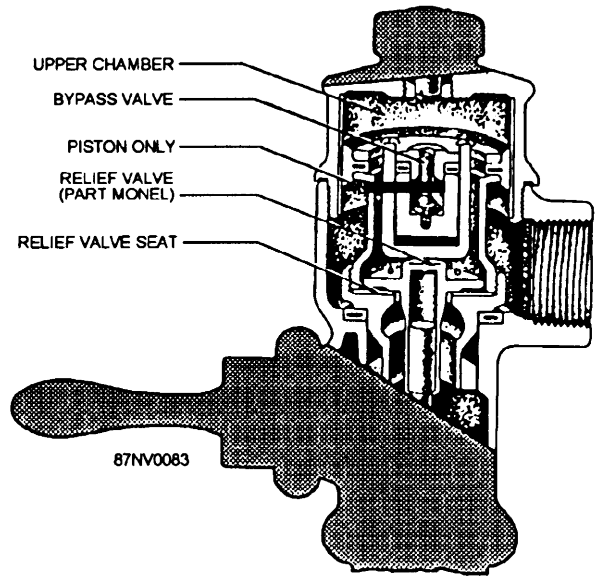


Figure 16-44.—Piston-type flushing valve.

If the relief valve fails to seat properly, there may be enough leakage to prevent the upper chamber of the valve from filling. The piston will therefore remain in the open position. Inspect the relief valve seat for dirt or other foreign substances that may be causing the relief valve to tilt. If these substances are present, disassemble the piston, wash the parts thoroughly, and reassemble. Replace wornout washers, making sure that the surface upon which the washer sits is perfectly clean. If any old rubber sticks to the metal surface, scrape it off.

Corrosion of the bypass valve in the center of the top plate will also cause continuous flow. The water is unable to pass into the upper chamber of the valve. Therefore, no force is exerted on the piston to move it downward to its seat. Very dirty water passing through the system can clog the bypass and deprive the upper chamber of water. Pipelines in a new installation should be thoroughly flushed out before they are placed in operation. If not, the pipe dope or dirt accumulated in them can also stop up the bypass valve.

The same condition can arise in a diaphragm valve. If chips or dirt carried by the water lodge between the relief valve and disk, the relief valve will not seat securely. The leakage will then prevent the upper chamber of the valve from filling with water. The valve will then remain in the open position, since there will be no pressure to force the diaphragm to seat.

Short flushing can occur only in a diaphragm-type valve. If the disk, diaphragm, and guide have not been assembled tightly, you may have to reassemble them to get proper operation. Sometimes you may find that someone has tampered with the bypass tube. It may be enlarged so that the water passes so rapidly into the upper chamber that it closes off the valve before the desired volume has been delivered. Also, someone may have oiled or greased the valve parts. It may have been done to make the valve operate more easily. However, the oil or grease ruins the rubber parts and interferes with the action of the valve. You may be called upon to correct short flushing in a water closet.

You should first check to see if the correct type of valve has been installed. If a urinal valve has been installed by mistake, the valve will not be short flushing. It is merely delivering the three-fourths gallon of water for which it is set.

PRESSURE-REDUCING VALVES

Pressure-reducing valves are installed in branch lines of the firemain to reduce the water pressure to a working level for the flushing system. You will probably do the maintenance and repair on these pressure-reducing valves.

The most common problems in these valves are ruptured diaphragms, binding of the O-ring or cup washer, and chattering. A Monel insert is now used to prevent the erosion of the valve body where the O-ring seals.

A ruptured diaphragm is easily detected, for water from the small hole in the spring chamber casing will be evident.

When you have a drop in water volume, check the valve's O-ring or cup washer. If the discharge pressure of a reducing valve becomes greater than the spring pressure, the volume will drop to almost nothing.

Chattering is more of a nuisance than a real problem. It is caused by the fast opening and closing of the reducing valve. This occurs when only one or two water closets are flushed at the same time and water supply is greater than demand. Usually most reducing valves are designed to handle the larger systems. When the demand is small, volume is supplied quickly and the valve, in turn, closes quickly. This rapid opening and closing is what causes the noise. A constant flow in the urinals will probably stop the chattering.

VALVE LEAKAGE AND STICKING CAUSES

During normal operation of valves, the use of a wrench to open or close a valve is prohibited. However, if a valve is jammed in the open or closed position, a wrench may be used to unjam the valve. However, because of the danger of damaging the valve disk due to overloading of the stem and disk, you should take extreme care when using a wrench. Where extreme difficulty is experienced in opening and closing a valve, isolate the valve and disassemble for inspection to determine the cause of the problem. Inability to open high-pressure steam, flexible wedge, gate valves with the normal operating mechanism or handwheel may be an indication of body overpressurization. If the steam supply to the valve is not shut down immediately, the results may be catastrophic.

Seating Problems

Leakage through the valve is generally caused by the disk and seat failing to make a tight joint, and may result from conditions described in the following paragraphs. Additional information on seating problems can be found in *NSTM,* chapter 505.

—Foreign Substances. Foreign substances, such as scale, dirt, waste, or heavy grease may become lodged on the seat so the disk cannot be seated. If obstructing material cannot be flushed through, disassemble and clean out the valve.

—Scoring. Scores in the seat or disk are caused by attempting to close the valve on scale or dirt, or by erosion. If damage is slight, the valve may be made tight by grinding; if damage is more extensive, reseat the valve and then grind or replace.

—Cocked Disk. The disks may be cocked if the feather guides fit too tightly or if the spindle guide or valve stem is bent.

—Damaged Seat or Disk. The valve body or disk may be too weak, permitting distortion of the valve seat or disk under pressure or closing force.

—Improper Disk-to-Seat Contact. The disks and seat may not have been machined properly, preventing tight disk-to-seat contact.

—Extraneous Leakage. Leakage paths may occur behind inserted seats or threaded seat rings.

—Casting Defects. Casting defects may be present in the valve disk or body, particularly in new valves.

—Seat Warping. In brazed valves, seat warping results from excess heat applied to the valve body during brazing.

Stuffing Box

Stuffing box leaks may be remedied by tightening gland nuts, or by adding rings of packing as required. Continued leakage may indicate a need to replace all packing in the valve. Do not set up or pack the gland so tightly that the stem sticks. Persistent stuffing box leaks are usually caused by a bent or scored valve stem. Considerable trouble with stuffing box leaks may be avoided if valves are installed with the valve stem pointing up. Before you alter the position of a valve stem, you should consider convenience of operation and availability of space for removing the bonnet, stem, and disk.

EXTERNAL PRESERVATION OF VALVES

Now we will discuss the external surfaces of valves that require painting, with the following exceptions:

- Valvestem
- Valve stem bushing
- Valve gland
- Any threaded surfaces

For valves that operate above 300°F (when the fluid contained is above 300°F), two coats of high-temperature aluminum paint should be used. No primer should be used on these high-temperature valves.

For valves that operate below 300°F, primer paint should be applied to match the surrounding area. Note that all steam valves operate above 300°F. Valves made of noncorrosive material (stainless steel, bronze, Monel, and so forth) do not require painting.

Solid film lubricant conforming to MIL-L-23398B is authorized for valve preservation where temperatures do not exceed 500°F.

After you have finished painting, check the valve to ensure that no paint has inadvertently been placed on any of the excepted surfaces noted earlier. If so, remove all such excess paint.

INSTALLATION AND REPAIR OF INSULATION

A basic rule for repair of insulation is that you do not allow the insulating material to become moist. Moisture reduces the effectiveness of the material, and may cause long-term disintegration. Large air pockets in the insulation cause large heat losses, so be sure to fill and seal all cavities or cracks. Hangers or other supports should be insulated to prevent loss of heat by conduction.

All sections of pipe coverings should be tightly butted at the joints. They should be secured with wire loops, metal bands, or lacing. Secure the block insulation with 18 gauge steel wire and galvanized mesh wire, or expanded metal lattice. Use insulating cement to fill all crevices, to smooth all surfaces, and to coat wire netting before you apply final lagging.

MOISTUREPROOFING is just as important in high-temperature insulation as it is in low-temperature insulation. In the former case, heat is lost because of evaporation. In the latter case, condensed moisture may freeze. Either case reduces insulating efficiency and eventually the insulating material disintegrates. Wet insulation also tends to corrode the piping.

Pipe fittings, flanges and valves may be insulated with the same material used for piping, but they require different methods.

REMOVABLE INSULATION is usually installed in the following locations:

- Manhole covers, inspection openings, turbine casing flanges, drain plugs, strainer cleanouts, and spectacle flanges
- Flanged pipe joints adjacent to machinery or equipment that must be broken when units are opened for inspection or overhaul (fig. 16-45)
- Valve bonnets of valves larger than 2 inches IPS that operate at 300 psi and above, or at 240°F and above
- All pressure-reducing and pressure-regulating valves, pump pressure governors, and strainer bonnets

Some small units of machinery or equipment, such as an auxiliary turbine, are located in tight places. It would be difficult to install both permanent insulation over the casing and removable and replaceable covers over the casing flanges. In these situations, the entire insulation may be made removable and replaceable.

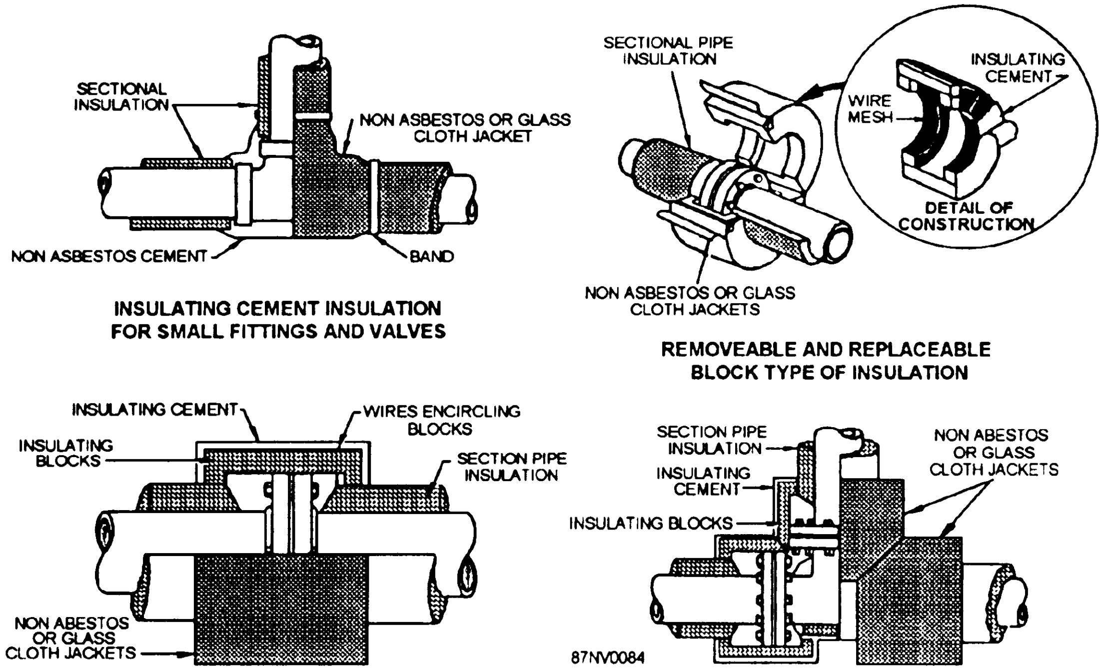


Figure 16-45.—Permanent-type insulation of pipe fittings, flanges, and valves.

Covers shouild fit perfectly and should project over adjacent permanent insulation.

Any one of the following methods of fabrication is acceptable for piping components:

1. Covers may be made in two halves out of thermal insulating felt enclosed with 0.008-inch diameter knitted wire mesh on the inside and end surfaces. The outside of the covers will have a fibrous glass fabric conforming to MIL-C-20079, class 9. Each half cover may be sewn and quilted with polyetrafluoroethylene (PTFE) coated fibrous glass yarn or thread. The covers may also be fastened with stainless-steel staples to provide uniform thickness, strength, and rigidity.

2. Covers exposed to temperatures of 450°F and above must have a 0.008-inch diameter knitted wire mesh on the inside surface and on the ends. Fibrous glass cloth conforming to MIL-C-20079, class 9, must be used on all outside surfaces. Covers for use at temperatures of 850°F and above must have a filling consisting of fibrous glass felt, MIL-I-23128. The knitted wire mesh must be made of 304 annealed stainless steel.

Either of the following methods of fabrication is acceptable for removable and replaceable covers for machinery and equipment:

1. Covers may bc similar to the flexible fiberglass type described for piping components.

2. Covers should be made in sections formed of insulating block and held together with wire and adhesive cement. These sections should be covered with a 1/2-inch thickness of finishing cement, and lagged. Lace with hooks, rings, washers, and wire, or brass snap fasteners to secure the covers.

Observe the following general precautions when you apply and maintain insulation:

1. Fill and seal all air pockets and cracks. Failure to do this will cause large losses by conduction and by convection currents.

2. Seal the ends of the insulation and taper off to a smooth, airtight joint. Use sheet metal lagging at joint ends or other points where insulation is liable to damage. Cuff flanges and joints with 6-inch lagging.

3. Fibrous glass cloth covering fitted over insulation should be tight and smooth. It may be sewed with yarn or may be cemented on.

4. Keep moisture out of all insulation work. Moisture is an enemy of heat insulation. Any dampness increases the conductivity of all heat-insulating materials.

5. Insulate all hangers and other supports at their point of contact from the pipe or other unit they are supporting. Otherwise a considerable quantity of heat will be lost through the support via conduction.

6. Sheet metal covering should be kept bright and not painted unless the protecting surface has been damaged or has worn off. The radiation from bright-bodied and light-colored objects is considerably less than from rough and dark-colored objects.

7. Once installed, heat insulation requires careful inspection, upkeep, and repair. When you remove lagging and insulation to make repairs, replace it just as carefully as when it was originally installed. When replacing insulation, make certain that the replacement material is the same as the original. Old magnesia blocks and sections broken in removal can be mixed with water and reused in the plastic form for temporary repairs. Save all old magnesia for this use.

8. Insulate all flanges with easily removable forms, which can be made up as pads of insulating material wired or bound in place. Cover the whole thing with sheet-metal casings, which are in halves and easily removable.

Lag the main steam, auxiliary steam, auxiliary exhaust, feed water, and steam heating piping systems to hold in the heat. Lag the circulating drainage, fire, and sanitary piping systems to prevent condensation of moisture on the outside of the piping.

Inspect pipes, machinery, and allied equipment periodically for evidence of broken or loose insulation or lagging materials. The insulating and lagging materials used and the method of installation will vary according to the service. Guidelines for insulation requirements, installation, and repairs are covered in MIL-STD-769 and in the *NSTM*, chapter 635.

MISCELLANEOUS REPAIRS

Most of your trouble will be in flushing and firemain systems. This section tells you how to locate trouble spots and how to correct troubles in these systems.

On ships built during and since World War II, these two systems have been made of copper-nickel pipe and tubing with bronze fittings. The valves for the most part are bronze-bodied with Monel seats and disks. These systems are assembled by brazing with a silver-base alloy.

When brazing on these systems, you need to be sure that all water is secured. It is impossible to get a satisfactory braze with water in the line. Never try to braze until the line has been drained and completely secured. You may want to break the line at a union or flange and slip a piece of sheet metal between the faces. This will divert a trickle of water before it reaches the section on which you are working.

REPAIRING DRAINAGE SYSTEMS

Trouble calls on drainage systems are frequent, but most of the troubles can be readily fixed. However, you must know how and where the drain lines run.

Snakes, suction cups, air pressure, and water pressure are usually used to free lines of obstructions. The use of a snake or a suction cup usually involves no danger. But when you use air or water pressure, you will have to be careful. Make sure that all the other drains connected to the line you are working on are closed. If there are outlets in which no closure is installed, you will have to drive a wooden plug into the drain. The plug may be in a compartment other than the one in which you are working. If so, have someone watch the plug to let you know if it blows out. Otherwise, you may think that the drain you are repairing is satisfactorily discharging water, when you are actually flooding another compartment.

Locating the exact trouble spot in a clogged line is simply a matter of knowing what drains run into a common discharge line. When you are called to a job, you should first check the drain line to see what sanitary facilities drain into it. Then go back along the line to determine what is free and running and what is stopped up.

Figure 16-46 is a diagram that should help you understand how to check back along a drain line to

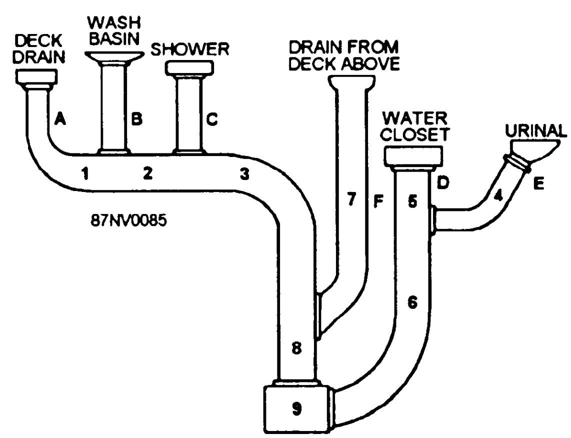


Figure 16-46.—How to check for the location of trouble spots in a drain line.

locate the source of trouble. If drain A is stopped but B and C are running, the trouble is located somewhere in section 1 of the drain line. If the A and B drains are stopped but C is running, the trouble is in section 2. If A, B, and C are stopped but F is running, 3 is the section that needs attention. If A, B, C, and F are stopped but D and E are working, check section 8. If D is working and E is stopped up, check section 4. If E is running but D is stopped, check section 5. If both D and E are stopped but A, B, C, and F are running, the trouble will lie somewhere in section 6. If all these facilities are stopped, the trouble will be located at section 9.

REPAIRING STRAINERS

Strainers are installed in piping systems to prevent the passage of foreign matter that could obstruct valves or damage the machinery or appliances.

Use these procedures to clean a strainer fitted with a drain in the bottom and an air cock vent in the top or cover. Close the valves leading to the strainer and open both the drain and the vent cock. This permits the discharge of oil and sludge and purges the chamber of air. Close the drain before you reopen the valves. Then close the vent after you have reopened the valves. When no air cock vent is provided in the strainer cover, first close the valves leading to the strainer and then open the strainer cover. Do the latter step gradually because, if the strainer is air bound, oil and foreign matter will spray out. Remove the strainer basket, replace it with a clean one, secure the strainer cover, and open the valves. Check to make sure there are no leaks.

Clean, spare strainer baskets of the necessary size and type, plainly marked or tagged, should be kept in a rack convenient to each strainer. The removed basket can usually be cleaned with a jet of steam. If it is heavily encrusted, it should be boiled in a solution of boiler compound.

REPAIRING TRAPS

Traps must be located below the lowest point to be drained. Also, they should be easily accessible for inspection and repair.

The capacity of a trap is determined by the ejection pressure, the pressure against which it is discharged, and the area of the discharge orifice. Proper observance of pressure limits is necessary if traps are to function efficiently. They should not be subjected to pressures higher than those that they are designed to carry. A trap will normally discharge condensate against a head of 24 inches of water for each pound of pressure differential between the trap and the drainage system.

Inefficient trap operation is usually caused by one of the following problems:

- The discharge valve is leaking because of scoring by dirt or scale.
- The discharge valve is leaking because of a punctured float or basket.
- The working parts are adrift.
- The discharge valve is too small.
- The discharge valve does not seat properly.
- The trap is air bound.
- The sediment has collected in the bottom of the trap.
- The trap does not accumulate enough water to close.
- The bypass valve is open or leaking.

If the discharge valve is too small, it may be possible to enlarge the discharge orifice, but only if the float leverage will handle a larger valve. If the internal load on the valve equals or exceeds the pulling power of the leverage, the valve will not open. It may be possible to raise the leverage, or it may be easier to direct part of the discharge to another trap. However, never overload a trap by leading too many additional drains to it. Keep this in mind when you make alterations in a piping system.

As a temporary remedy for a trap that is discharging at less than capacity, you can crack the bypass valve just enough to carry off the excess water. Remember that if the quantity of condensate diminishes, the bypass valve will deliver steam. If a trap does not accumulate enough water, pour one or two buckets of water on the trap. This should cause enough condensation to overcome the trouble. If not, you will have to shut off the trap, remove a fitting, and prime with water through the opening.

Inspect drainage systems regularly to detect leaks that could easily pass unnoticed. In freezing weather, the drains for auxiliary machinery in exposed locations should be drained. If necessary, they should be broken to prevent possible damage to the machinery.

MATERIAL REPLACEMENT

When a section of an existing piping system must be renewed, select the materials according to the following general considerations.

Choose replacement materials of the same material, size, and wall thickness as the original. This will ensure that the original design of the system's capacity, thermal expansion, and contraction is not changed. It will also prevent the setting up of a galvanic couple between dissimilar materials, with its attendant electrolytic corrosion.

Materials used in piping systems on ships built to specifications should be built to military standards. Military standards require that materials used in piping systems on naval ships have a higher resistance to corrosion and shock damage. They also must be of the lightest weight possible.

In the past, there have been numerous incidents involving the failure of piping system components. Several of these incidents have resulted in lost of equipment and even the death of shipmates. Most of these incidents have resulted from the careless maintenance practices and incorrect materials used while performing maintenance or repairs. Therefore, you should always consult the applicable ships and system drawings when choosing replacement or repair materials. If the applicable blueprint is not available, consult other MIL-STDS, technical manuals, operator manuals, or repair manuals for correct materials and repair procedures. If you deviate from original design specifications, obtain prior approval from competent authority before proceeding with the repair.

SYSTEM AND EQUIPMENT ISOLATION WHEN CONDUCTING MAINTENANCE AND TESTING

Pressure barriers, which prevent the escape of a pressurized fluid from a system, are necessary when conducting maintenance on piping systems to prevent endangering personnel and equipment. These dangers include personnel injury due to high temperatures, projectures from high-pressure systems, wetting of electrical equipment, or unintentional venting or draining of adjacent systems.

When isolating a system for component repair or replacement, the type of barrier used for isolation is an important consideration. Examples of allowable pressure barriers are a closed valve, blind (blank) union, blind (blank) flange, or spectacle flange, all of which must be capable of withstanding system pressure and temperature during performance of the maintenance evolution. Some gate valves are equipped with internal or external bypass features and may be used as a barrier only in one direction if the bypass is open. A gagged relief valve may unseat with sufficient reverse pressure, so consider a gagged relief valve a pressure barrier only for maintenance performance downstream of the relief valve. Solenoid-operated valves that have a fail to shut feature tend to seat with system pressure, and do not have internal bypasses that cannot be isolated. These valves may be used as barriers for maintenance performance downstream in the direction in which pressure tends to seat the valve. Do not use other solenoid-operated valves as pressure barriers. Do not use lift, swing, or stop check valves seated by pressure only, ungagged relief valves, four-way valves, or feed regulating valves as pressure barriers. Valves used for throttling are subject to erosion and may not be good pressure barriers.

At least two pressure barriers are required between the maintenance area and any high-temperature (200°F or more) fluid. Where possible, open a tell-tale drain valve between the two barriers to warn if one barrier is leaking. Provide at least two pressure barriers, since high-temperature (above 200°F), high-pressure liquid will flash, providing a continuing pressure source, causing discharge of large quantities of high-temperature fluid and endangering personnel in the maintenance area if leakage should occur. If necessary, an exception to this requirement may be made if the source of high-temperature liquid is separated from the maintenance area by a single-pressure barrier and a sufficiently large volume of low-temperature (below 200°F) liquid. The volume of the low-temperature liquid must be sufficient to allow personnel performing the maintenance to get clear and to secure the source of high-temperature liquid in time to prevent its discharge into the maintenance area if the single-pressure barrier should fail.

A potential danger in component repair or replacement lies in inadvertent or accidental operation of the isolation valves. Tag out all valves and their controls to prevent inadvertent operation. If the control valve of an actuator is electrically operated, have the fuses removed from the circuit or disconnect the electrical connector so that the operator of the control valve cannot be accidentally energized. If the control valve of an actuator is air operated, shut and tag out the air supply isolation valve so that the control valve cannot be accidentally operated by air.

When piping is under repair, secure and tag out the isolation and cutout valve connecting the dead portion(s) with the live portion to indicate that personnel are working on the dead portion(s). Do not remove the tags until it is determined that this will not create a hazard to personnel working on the dead portion or until the work on the dead portion is completed. Open drain connections to atmosphere on all the dead interconnecting systems for visual drainage observation.

PRECAUTIONS FOR BREAKING LINE AND VALVE BONNET

Before breaking a line or valve bonnet joint, or cutting into a line, ensure that the following conditions are in effect:

1. Shut and secure valves isolating the section in such a manner that they cannot be opened accidentally, either locally or remotely.

2. Completely drain the line or vent with no pressure on the line.

3. Take precautions to prevent fire or explosion from flammable fluid.

4. Shut and tag out valves isolating the section according to current shipboard and applicable OPNAV instructions.

5. Provide adequate ventilation.

6. Provide any compartment that contains a fluid energy accumulator (or to which a large volume of fluid energy can be released) with two-barrier protection if the released volume, in standard cubic feet, is twice the compartment volume.

In breaking flanged joints, make sure that the two diametrically opposite securing nuts remain tight while the remainder are slackened. Then slacken these two nuts sufficiently to permit breaking the joint. After the joint is broken and the line or valve proven clear, remove all nuts.

PROTECTION OF ELECTRICAL EQUIPMENT

Before working on any piping system, make a survey to ensure that under no condition can any liquids splash on exposed electrical equipment. If there is any possibility of splashing a switchboard or other electrical equipment, take the following steps:

1. De-energize electrical equipment and cover with a waterproof material.

NOTE: If it is not possible to de-energize the electrical equipment before work on the piping system begins, completely cover with a rubber sheet or other nonconductive waterproof material. Do not restrict ventilation to the point that equipment will overheat.

2. Open piping away from electrical equipment, at a lower level if feasible, to ensure that the line is completely drained and unpressurized.

Early detection and correction of defects will reduce the amount of effort required for repair and will provide more satisfactory operating conditions.

LEAKAGE

Take up small leaks in gaskets immediately. If allowed to persist, the leaks will become progressively worse and may eventually cause a blowout. In addition, flange faces in high-pressure joints will become cut and require rebuilding and refacing.

When continuing or repeated leakage, breakage, or failure occurs in a piping system, determine and correct the cause. Common causes are as follows:

- Misalignment
- Inadequate allowance for thermal expansion, working of the ship, and other movements
- Vibration
- Hydraulic transients (water hammer)
- Rapid temperature changes
- Corrosion
- Erosion
- Galvanic action

CAUTION

It is of the utmost importance that NO explosive conditions exist prior to using spark-producing tools or burning equipment.

THREAD LEAKS

All leaking threaded joints that cannot be tightened with a reasonable amount of pull-up should be taken apart, cleaned, and examined to remove bad thread conditions. Recoat with a compound suitable for the intended service, and carefully reassemble to avoid any other thread damage. Poorly cut threads are a constant source of trouble with threaded joints. Therefore, it is essential that thread cutters receive proper use and care.

Various thread leak causes and corrective measures to be taken are listed in table 16-6.

PREPARATION OF PIPES FOR REPAIR

Prepare pipes requiring repair according to the procedures described in the following paragraphs:

1. Remove all foreign material such as paint, heavy scale, grease or other contaminants from the area of pipe or tubing for at least 6 inches on each side of the repair area; it is not necessary to polish the pipe. The pipe or tubing should be clean, dry, and free of solvents and flammable vapors.

2. Pipe or tubing requiring repair may show cracks or other defects indicative of incipient failure. In the area to be repaired where such defects are not obvious, liquid-penetrant test the area before pressurizing to ensure that undetected defects are not present.

For additional information on the characteristics, special requirements and procedures, and the types and frequency of tests and inspections to be conducted on specific piping systems, refer to *NSTM*, chapter 505. For more information on the repair of hydraulic systems, consult *NSTM*, chapter 556.

Table 16-6.—Thread Leak Causes and Corrective Measures

Cause of Trouble	Correction
Rough Threads:	
Dull chasers	Sharpen
Insufficient lubrication	Use plenty of good oil
Excessive or insufficient lead cutting	Grind properly Grind to correct angle
Broken tooth in chaser leader	Grind out entire tooth
Chaser not set to form true cutting circle	Clean slots, set chasers to true cutting circle, grind chasers, if necessary, to a uniform length
Shaved Threads:	
Improper lead of chaser	Regrind lead
Chasers not tracking properly	Keep slots clean
Chasers not set in correct rotation	Correct setting
Carriage travel retarded (machine only)	Repair carriage
Wavy Threads:	
Die or chasers not true (manual only); loose chasers (machine)	Center die or chasers; get new die head
Thumb screws not tight (manual only); worn cam in head (machine)	Tighten with wrench; get new die head
Worn-out lead screws (manual only)	Get new die stock
Cuttings or dirt in chaser slots (manual only)	Keep slots clean
Shoulders:	
Pipe ends not square (manual only)	Recut square and rethread
Die and chuck not aligned (machine)	Check and realign

EQUIPMENT TAG OUT

Whenever you make repairs to piping systems, you will be required to isolate and tag out that section of the system. The tag-out program provides a procedure to be used when a component, apiece ofequipment, a system, or a portion of a system must be isolated because of some abnormal condition. The tag-out program also provides a procedure to be used when an instrument becomes unreliable or is not operating properly. The major difference between equipment tag-out and instrument tag-out is that labels are used for instrument tag-out and tags are used for equipment tag-out.

Detailed information on equipment tag-out procedures can be found in chapter 1 of this manual.

SUMMARY

You will make repairs to piping systems and valves frequently during your naval career. Normally you will make permanent repairs that require you to make templates, targets, and flanges. But, you need to know how to use the Metallic Pipe and General-Purpose Damage Control Kit to make a temporary repair in the event of an emergency.

When you have gained experience, you will make bends in piping and tubing without affecting the quality of the material or the operation of the system. However, always remember that safety comes first. Use the tag-out system to prevent the injury of personnel or other damage from occurring.

CHAPTER 17

SEWAGE SYSTEMS

LEARNING OBJECTIVES

Upon completion of this chapter, you will be able to do the following:

- *Explain the ways local waters become polluted, and recognize the means of controlling pollution aboard ship.*
- *Identify the pollution control acts and discuss the contents of each.*
- *Identify the components of the collection, holding, and transfer (CHT) system, and describe the function of each component.*
- *Identify the different types of CHT systems used aboard Nay ships, and describe the modes of operation.*
- *Describe the procedures for performing preventive maintenance on holding tank systems.*
- *Describe the basic sanitation precautions and safety procedures for the prevention of disease and personnel injury.*

INTRODUCTION

One of our major concerns is the pollution of U.S. waters. Our streams, lakes, and coastal waters are being contaminated by vessels, factories, and individuals through careless dumping of harmful materials. These materials include everyday trash and refuse, oil, chemicals, sewage, and waste water.

In this chapter, you will learn about the administrative actions that have been taken to help eliminate the pollution of our waters. Most of the chapter will deal with systems used by the Navy, the health hazards, and the safety guidelines used in operating and maintainingsewage systems.

ENVIRONMENTAL POLLUTION CONTROL

It was once routine for ships to discharge sewage directly overboard. Then on October 18, 1972, Public Law 92-500 was passed by the Senate and the House of Representatives. It is known as the Federal Water Pollution Control Act Amendments of 1972. The objective of PL 92-500 is to restore and maintain the chemical, physical, and biological quality of the nation's waters. The goals set by PL 92-500 are as follows:

- To eliminate the discharge of pollutants into our nation's navigable waters by 1985.
- To attain water quality, where possible, for the protection of fish, shellfish, and wildlife, and to provide for recreation in and on the waters by July 1, 1983.

- To prohibit the discharge of toxic pollutants in toxic amounts.

- To provide federal financial assistance to construct publicly owned waste treatment plants.

- To develop and implement regional waste treatment management planning processes.

- To research, develop, and demonstrate the technology necessary to eliminate the discharge of pollutants into our nation's waters.

PL 92-500 covers the dumping of oil, chemicals, trash, and other materials into our streams and navigable waters. The section of the law that we are concerned with is section 312, which is the guideline for marine sanitation devices (MSDs). Revisions to PL 92-500 are listed in PL 95-217 of December 27, 1977. Other notices, directives, specifications, and instructions that govern MSDs are as follows:

- Department of Defense Directive 6050.4

- Code of Federal Regulations (CFR) 33 CFR 159 and 40 CFR 140

- United States Code, Title 33, Section 1322

- OPNAVINST 4700.31

- OPNAVINST 5090.1, Chapter 12

- *NSTM*, chapter 593

When you refer to these publications, be sure you have the current editions.

Since 1972, the Navy has been persistent in installing MSDs in naval vessels. All vessels were to be in compliance with the laws and regulations by April 1, 1981. However, some exceptions have been made. Department of Defense vessels may discharge overboard within the U.S. navigable waters (3-mile limit) if the vessels meet one of the following requirements:

- The vessel cannot keep all ship-generated sewage on board until it can be disposed of properly.

- The vessel is participating in military operations and exercises within the navigable waters and retaining the sewage on board would interfere with the operational effectiveness or pose a health hazard to the personnel on board.

- The vessel is anchored or moored and sewage reception facilities are not available or foul weather, poor visibility, or unsafe environmental conditions make the use of services unfeasible.

- The vessel is in overhaul, and operation of the MSD would interfere with ongoing repairs.

- The vessel's MSD is inoperable because of equipment malfunction or equipment installation or repairs within the system.

The health and safety of the crew is to be the primary consideration. If the sewage is to be discharged overboard, the commanding officer must ensure that the discharge is as far from land as possible and the amount being discharged is kept to a minimum. Sanitation is a major concern. It needs to be addressed before we discuss the various sewage systems.

SANITATION

Sewage is defined as a mixture of all liquid domestic wastes, especially human body wastes (fecal matter and urine). Sewage contains large numbers of microorganisms (hundreds of millions per milliliter), some of which are disease bearing, such as typhoid, polio, and infectious hepatitis.

Bacteria and viruses enter the human body through openings such as the mouth, nose, and open sores. Therefore, you should observe the following basic precautions when working in sewage handling areas:

—NEVER eat, drink, or smoke while working in sewage spaces or on sewage equipment.

—NEVER work on sewage handling equipment if you have open cuts or sores.

—Keep equipment clean at ALL times.

—Wash down ANY spilled sewage immediately before it dries. Use hot water and stock detergent initially and then follow with an authorized disinfectant where required. Do NOT use liquid soaps or unauthorized disinfectants. They may temporarily disguise inadequate cleanup procedures.

—Always follow recommended personal hygiene routines after working in a sewage handling area or after being in contact with sewage handling equipment.

—Install drip pans under comminutors and pumps located off the deck.

—Install drip pans under all valves, flanges, and take-down joints located in food preparation spaces, messing areas where eating utensils are washed, and living spaces.

—Keep a close watch on the sewage system and take immediate corrective action on all leaks.

—If you handle or connect sewage transfer hoses, do not handle any potable water hoses until you wash yourself and change into clean clothing.

—Have the gas-free engineer check spaces, such as holding tanks and voids, before you use any open flames, flashlights, or other electrical equipment in or near them.

INSPECTIONS

Various inspections must be conducted periodically on the sewage systems and associated equipment. These inspections are required by type commander instructions, NAVMED P-5010-7, and *NSTM*, chapter 593, and are as follows:

—A visual inspection of MSD componenets by a Medical Department representative (MDR) as part of the routine habitability and sanitation inspection program. The MDR's routine inspection should be limited to those spaces where there is an interface between MSD components and the food service areas, living spaces, and medical spaces. Contamination of these spaces are likely to result in disease outbreaks if undetected or not properly cleaned and disinfected.

—Regular inspection of MSD components for leaks by appropriate engineering personnel responsible for the compartment in which MSD components are located.

All leaks, spills or other sources of contamination observed during these inspections or at any time shall be promptly reported to the executive officer, engineering officer/damage control officer, and the MDR. Immediate and appropriate action should be taken to stop the leak and properly clean and disinfect the contaminated area.

DISINFECTANTS

If equipment or personnel are located in sensitive areas or are contaminated with sewage to an extent that disinfection is required, the items listed in the following paragraphs should be used for shipboard use. A disinfectant will do little good unless sewage solids are removed from the equipment or surface.

NOTE: If in doubt concerning the use of disinfectants, consult the medical officer or senior MDR.

Use care when you store, mix, and use any of the following items. Follow all of the manufacturers' instructions exactly. While other disinfectants presently in the stock system may perform equally as well, you should not make substitutions unless properly authorized.

Decks, Bulkheads, and Equipment

When you are required to disinfect a compartment and the installed equipment, use one of these authorized disinfectants:

PHENOL BASE: Germicidal and fungicidal concentrate phenolic, dry type; NSN 6840-00-753-4797.

IODINE BASE: Providone-iodine solution, NSN 6505-00-754-0374.

IODINE BASE: Disinfectant, germicidal, and fungicidal concentrate (iodine type); NSN 906840-00-526-1192.

Hands

After working on sewage systems, sewage equipment, or cleaning up from a sewage spill, disinfect your hands. The following two cleansers are authorized for this purpose:

IODINE BASE: Detergent, surgical antiseptic sudsing skin cleanser; Prepodyne surgical scrub (use like liquid hand soap-full strength with water and lather); NSN 9P7930-00-282-9699, 1 gallon, NSN 9P7930-00-985-6911, 5 gallons, NSN 9P 7930-00-282-9700, 50 gallons.

SURGICAL SOAP: Betadine; NSN 9G 6505-00-914-3593.

HYGIENIC PRACTICES

The following housekeeping, sanitary, and hygienic practices must be followed:

—If you connect or disconnect sewage transfer hoses, you must not handle potable water hoses until after you have washed your hands and changed clothes.

—If you perform maintenance activities where sewage contamination is a possibility, or if you connect or disconnect sewage hoses, you must wear rubber gloves, rubber boots, coveralls, and a faceshield.

—Use standard stock detergent and hot water to wash down areas, surfaces, and fittings that are contaminated with sewage. If required, follow with an authorized disinfectant.

—Make regular use of the washup facilities provided in or adjacent to the CHT pump spaces to minimize the spread of contaminated products.

—If your shipmates work in sewage spaces or on CHT equipment, caution them against smoking, eating, or drinking before they wash up thoroughly with hot water and soap.

When you complete any CHT maintenance, you must wash affected areas with a solution of hot water and stock detergent.

CONTAMINATION PREVENTION PROCEDURES

The following standards have been established as guidance to those responsible for maintaining CHT sewage systems aboard ship.

Equipment for Personnel

The following equipment must be used by personnel who maintain CHT systems:

- Coveralls (one set for each individual)
- Goggles and faceshield (one set for each individual)
- Hood-type hats (one set for each individual)
- Rubber boots
- Plastic bags (one for rubber boots and gloves and one for coveralls)
- Respirator

Equipment/Facilities Within CHT Spaces

The following equipment/facilities must be available within all CHT spaces:

- Hand washing sink with potable water
- At least one of the disinfectant or detergent items listed in the Decks, Bulkheads, and Equipment section and one listed in the Hands section
- Hand drying facilities
- Plastic trash can bags

PERSONNEL CONTAMINATION PREVENTION PROCEDURES

You must not enter contaminated spaces/tanks without protective equipment and clothing.

Put on protective clothing and equipment. You should use an approved respirator (1) before entering a contaminated compartment and (2) when entering CHT tanks. Before leaving contaminated spaces, take the following precautions:

1. Scrub the affected areas with hot water and stock detergent. Then follow with an authorized disinfectant if necessary.

2. Remove protective clothing and equipment.

3. Place clothing in plastic bags maintained outside the space, using caution not to contaminate the outside of the bag.

4. Secure the plastic bag. (**NOTE:** The plastic bags must not be allowed in an immediate maintenance area.)

5. Clean boots, goggles, and respirators with hot water and a stock detergent. Then disinfect with one of the solutions listed in the Disinfectants section. Disassemble equipment for complete cleaning.

6. Place disinfected equipment outside the contaminated space as it is cleaned.

7. You must completely scrub your hands, lower arms, and face in that order with hot water and soap and dry them with equipment provided in the space.

8. Place paper towels or other remaining waste or cleaning materials in doubled plastic trash can liners and then discard them with the ship's trash.

9. After completing these necessary actions, you may leave the space.

10. Immediately transfer the plastic bag with the contaminated clothing enclosed to the laundry for washing.

LAUNDRY PROCEDURE

After you have completed your work on the sewage system or cleanup of a sewage spill, deliver the plastic bag containing your clothing to the laundry. The laundry personnel should clean the clothing used during maintenance or cleanup procedures using standard laundering procedures.

CERTIFICATION OF SPACE HABITABILITY

When a contaminated space has been sanitized, the senior MDR inspects the space and certifies, in writing to the commanding officer, that it has been adequately decontaminated. Until the space has been certified, consider it contaminated. All personnel entering the space should follow the decontamination safety procedures outlined in the previous paragraphs.

WATCH AND TRAINING REQUIREMENTS

Once each watch, conduct an inspection of CHT tanks, pumping systems, and piping. Ensure watertight integrity and the absence of contamination leaks, overflow, or spillage. Log these inspections. Report any discrepancies immediately to the CDO in port and to the OOD when underway.

Training should be provided for personnel who decontaminate spaces contaminated by raw sewage or effluent from the CHT system. This same training should also be provided to personnel whose duties require them to enter spaces subject to contamination.

NOTE: Notify the DCA and senior MDR on the status of any holding or other MSD whenever there is a threat to the ship by reason of hostilities, fire, flooding, or conditions that could turn the tank into a biological hazard to the ship's crew. Each ship should have developed plans and drills to eliminate or control the biological hazards from these occurrences.

COLLECTION, HOLDING, AND TRANSFER (CHT) SYSTEM

In 1972, the Navy began installing the CHT sewage collection system in ships that could use this method of water pollution control. The CHT concept is the cheapest and safest way to solve the sewage disposal problem aboard ship.

Most operational ships of the fleet will be equipped with CHT. These systems can hold sewage produced over a 12-hour period. If the CHT system is not feasible, another type of MSD will be installed. This TRAMAN will only discuss the CHT type of sanitation system.

CHT ELEMENTS

The CHT system accepts soil and waste drains from water closets, urinals, showers, laundries, and galleys. It is made up of three elements-the collection element, the holding element, and the transfer element-which are described and discussed in the following paragraphs.

The collection element consists of separate soil and waste drains that are equipped with diverter valves. Depending on the position of these diverter valves, the soil and waste drains can be diverted or directed overboard or into the CHT tank.

The holding element is a holding tank. The tank is designed large enough to hold all of the ship's sewage that would normally be generated over a 12-hour period.

The transfer element includes sewage pumps, overboard and deck discharge piping, and deck discharge fittings.

Collection Element

The CHT system plan requires that waste drains be kept separate from soil drains wherever practical until they reach the overboard diverter valve. From this point, they may be combined into a single drain line. All drains above the waterline may be diverted overboard by gravity. Drains located below the waterline cannot be diverted directly overboard and must use the CHT system as an ejection system. In this case, the CHT system must operate continuously.

NOTE: Waste drains are plumbing drains that service sinks, showers, galleys, and other similar drains that transport their waste water, which is known as gray water. Soil drains are plumbing drains that service commodes, urinals, and other drains that transport human wastes, also known as black water.

All drain piping is pitched to ensure rapid and complete drainage of the waste and soil drain systems. The piping pitch is l/4 inch per foot whenever possible, but not less than l/8 inch per foot relative to the ship's trim.

Garbage grinder drains connected to the waste drains have a minimum slope of 3 inches per foot. These drains also have a check valve to prevent backflow from the waste drain system.

Plumbing drains may pass through watertight bulkheads. Normally, each bulkhead penetration has a bulkhead stop valve. Each bulkhead stop valve is a full-port, plug-, or ball-type valve. The valve should be operable both at the valve and from the damage control deck. In some installations, diverter valves (three-way valves) are used to prevent progressive flooding through the CHT system drains. This eliminates the need for bulkhead stop valves.

Where CHT system valves are designated as damage control closures, the valve bonnet and handwheel are labeled, The labels are X-BAY, YOKE, or ZEBRA, with the direction to be turned marked by an arrow. Similar marking or labeling is shown on the remote valve operators, located at the damage control deck.

The piping primarily used in CHT systems is made of copper-nickel (90 to 10). The main drain headers are normally 4-inch pipe. However, some larger ships will have 6- or even 8-inch pipe.

For identification purposes, the piping will be stencilled as either a soil drain or waste drain. An arrow will also be stencilled on the piping to indicate the direction of flow. It is not necessary to color-code the piping. However, the valves and valve handles should be painted gold according to the color coding system.

Holding Element

We said earlier that the CHT tank is normally designed large enough for a 12-hour holding period, but the ship's size, shape, and mission will affect the volume of the tank. The number of tanks will vary from ship to ship. Each tank has inside surfaces that are generally free of structural members such as stiffeners, headers, and brackets. However, very large tanks may have swash bulkheads to dampen the movement of the contents of the tank. The tank bottom slopes about 1.5 inches per foot toward the pump suction. All internal surfaces of the tank are coated to prevent corrosion. (See *NSTM*, chapter 631 (9190).) Each CHT tank has a vent to the atmosphere, an overflow to the sea, and a manhole for internal maintenance.

The firemain connection is used to flush and clean the CHT tank. Seawater is sent into the top of the tank through washdown nozzles, which spray the inside of the tank. The tank should be flushed each week for 30 minutes whether in port or at sea. The firemain is used also to flush the discharge piping and the transfer hose when the ship is preparing to leave port but while it is still connected to the shore sewage fittings.

Transfer Element

Each CHT tank has two nonclog marine sewage pumps connected in parallel. The pumps may discharge sewage to a tender, barge, shore facility, or directly overboard, depending on the position of the discharge pump diverter valve. Each pump has a full-port, plug-, or ball-type suction and discharge valve and a discharge swing-check valve with a hold-open device. See *NSTM,* chapter 503, for an explanation of sewage pumps.

TYPES OF CHT SYSTEMS

There are two types of CHT systems, depending on the capacity of the holding tank. Systems with a tank capacity greater than 2,000 gallons use a comminutor (com-MIN-u-tor). A comminutor chops, chews up, and grinds fragments, and softens thick material into a semifluid consistency. Systems with a tank capacity of less than 2,000 gallons use strainers.

Comminutor-Type System

In comminutor-type systems, the comminutor, located in the soil drain or in the combined soil and waste drain, macerates (chews up) solids passing into the CHT tank. If the comminutor jams or plugs, a bypass line provides drainage around the comminutor into the tank. If a valve is fitted in the bypass line, it must always remain open during routine operation of the system. Isolationvalves are fitted directly before and after the comminutor to allow for maintenance. Also, most installations have an access opening for removing foreign objects that may jam or plug the comminutor.

The major components of the comminutor-type CHT system are discussed in the following paragraphs and shown in figure 17-1 (at the end of this chapter).

1. CHT tank: Each tank will have a capacity of 2,000 gallons or more.

2. CHT pump set: There is one set per tank; a pump set consists of the following components:

   a. Two motor-driven (mixed flow) centrifugal pumps

   b. Two plug- or ball-type suction valves

   c. Two plug- or ball-type discharge valves

   d. Two pump discharge check valves with a hold-open device

   e. A duplex pump controller

   f. A high-level alarm

   g. Liquid-level sensors

3. Comminutor: There is one in each soil drain or combined soil and waste drain entering each tank.

4. Aeration supply and diffusers.

5. Firemain flushing connections and washdown nozzle for spray cleaning the interior of the tank.

6. Piping, valves, and fittings.

COMMINUTOR SUBSYSTEM.—The comminutors are installed in the soil drain lines. They may be installed in any position as long as gravity flow can take place. However, a 20-inch clearance is required on the belt side to allow for the removal and repair of the cutter assembly.

The cutter assembly breaks up solids into smaller particles. Be sure that no metal objects go down the drains. Any metal over 0.010 inch thick can damage the cutter blades.

The comminutor is electrically operated. The shafts operate at different individual speeds for more effective breaking up of solids and for self-cleaning.

The comminutor does not have to be removed for scheduled planned maintenance. If the cutter assembly is to be removed, it should first be either hosed down or steam-cleaned. (Follow the sanitation procedures listed earlier under the Sanitation heading.) The assembly can then be removed by using extreme care. The inside diameter of the housing is a sealing surface, and damage to it could cause leakage.

AERATION SUBSYSTEM.—In the comminutor-type CHT system, air is supplied to the tank to prevent the contents from generating hydrogen sulfide gas (odor of rotten eggs) and also to keep solids in suspension. (See fig. 17-2, at the end of this chapter.) Air enters the tank at or near the top and is piped to nonclog air diffusers located at the bottom of the tank. These diffusers are spaced 2 feet apart. Air pressure of 5 to 12 psi from motor-driven blowers is supplied at the diffusers to overcome the hydrostatic head of the overlying liquid. In some systems, ship's service air is provided as a secondary source of the aeration. CHT systems in some aircraft carriers do not use blowers for aeration. Instead, they use ship's service air as the primary source of air for tank aeration. The aeration subsystem is operated when the CHT system is in any operational mode except the at-sea mode.

Strainer-Type System

The strainer-type system is basically the same as the comminutor system except that the strainer system does not have a comminutor or an aeration subsystem, and the holding tank is less than 2,000 gallons in capacity.

The strainer-type system has an overflow strainer within the CHT tank and an inflow strainer mounted on the discharge side of each pump. The drain collection pipe directs sewage flow through the overflow strainer where liquids may overflow into the CHT tank in the event the inflow strainer or the pumps become clogged. Solid and liquid wastes flow through the ball or plug valve and check valves until they reach the pump discharge piping. At this junction, the sewage flow passes through the inflow strainer where large solids are collected. Then they pass through the pump and back into the CHT tank. The inflow strainer limits the flow of solids, but liquids are allowed to pass through the pump into the tank. Each time the pump operates, its inflow strainer is cleaned by the reverse flow of liquid being pumped from the tank.

The major components of the strainer-type system are shown in figure 17-3 (at the end of this chapter) and are discussed in the following paragraphs.

1. CHT tank: The capacity of each strainer system tank is less than 2,000 gallons.

2. CHT pump set: There is one pump set per tank. A pump set consists of the following components:

   a. Two motor-driven (mixed flow) centrifugal pumps

   b. Two plug- or ball-type suction valves

   c. Two plug- or ball-type discharge valves

   d. Two pump discharge check valves with a hold-open device

   e. A pump controller

   f. A high-level alarm

   g. One liquid-level sensor for the high-level alarm

3. Inflow strainers with plug- or ball-type stop valves and swing-check valves

4. Overflow strainer inside the CHT sewage tank

5. Firemain flushing connections and washdown nozzle for spray cleaning the interior of the tank

CHT COMMON COMPONENTS

There are definite differences between the comminutor system and the strainer system, but the two systems are similar in several ways. The operational modes, hoses, pumps, alarms, level sensors, and controls are basically the same. The manufacturer and the size may differ from one system to the other, or even from one ship to the next. However, the operation of the equipment will vary only slightly.

Sewage Pumps

Each CHT system has a set of two sewage pumps. The pumps may be operated both at the same time or by alternating with each other. The pump transfers the sewage from the tank to the pier connection, or directly overboard. The destination of the sewage depends on the lineup of the piping and the diverter valves.

The pump suction is located one pipe diameter off the bottom of the tank. This maintains a flooded suction. The pump's impeller is a nonclog marine type. The semi-open impeller allows solids up to 2 l/2 inch in diameter to pass through. Double mechanical seals are used to prevent leakage. The oil reservoir of the seal is filled with 2190 TEP oil.

Drip pans or a coaming are installed to contain any leaks at the pump or pipe connections. The drip pans and coaming areas should be inspected regularly; if they have been contaminated, they must be cleaned and disinfected.

Full-ported suction and discharge valves are installed in the piping on the respective sides of the pump. These valves will either be ball or plug valves.

A spool piece consisting of a short flanged pipe is installed in the suction line near the pump. The spool is a convenience item to allow maintenance personnel to inspect the pump. If the pump is clogged or jammed, you can remove the spool and gain access to correct the situation.

Most of the new installations are fitted with oil-filled diaphragms to keep the sewage out of the sensitive parts of the pressure gauges. The pump has a vacuum/pressure gauge on the suction side, and a discharge/pressure gauge.

A special swing-check valve is installed in each pump discharge line to prevent one pump from pumping sewage back to the tank through the adjacent pump. The swing-checkvalve also prevents sewage from another nested ship from being pumped into the tank. These swing-check valves have a manual hold-open device to permit drainage of the discharge piping.

Piping Systems

The piping assembly for the CHT system should be straight with as few elbows as possible. A slight downward slope is needed to allow for gravity flow. The piping transfers soil and waste water from the source to the overboard discharge or to the CHT tank, depending on the operational mode.

The piping in the pump room should not be lagged. However, the piping outside the pump room should be lagged. Valves or flanges within the CHT system should not be lagged. This will allow ready detection of leaks. A drip pan will be installed under any valve or flange located in food preparation or food storage areas, medical spaces, or spaces where leakage can reach any bilges that comes into contact with potable water tanks. This will help detect leakage and prevent the spread of contamination.

A firemain washdown system is used to flush the tank, discharge piping, and hoses. The pump room can also be washed down. The water left in the pump room can be disposed of through the pump-room sump using the installed eductor.

A relief valve set at about 125 psi is installed in the discharge piping system. This valve prevents excessive pressure in the hose during the flushing process.

Controller, Alarms, and Level Sensors

The CHT system provides for both manual (MAN) and automatic (AUTO) operation. In the MAN 1 mode, the operator may start either or both pumps independently of the tank liquid level sensors. In the MAN 2 mode, the pumps stop at the low-liquid level (10 percent). In the AUTO mode, the pump controller automatically performs the following functions as a result of signals from the level sensors in each tank:

- The controller alternates the duty or operating pumps.
- The low-liquid level sensor stops the duty pump when the liquid level reaches approximately 10 percent of the tank volume to maintain flooded pump suction.
- The 30 percent liquid level sensor signals the controller to start the duty pump.
- The 60 percent liquid level sensor signals the controller to start the standby pump in the event of failure or inadequacy of the duty pump.
- The 85 percent liquid level sensor provides a visual (sight) and audible (sound) high-level alarm signal. The high-liquid level alarm operates both audibly and visually in the CHT pump area, in damage control central, and on the quarterdeck. The sound alarm in the pump room can be silenced

locally while the system is being serviced. In some installations, the CHT pump-room area is equipped with a flooding alarm that is monitored at a remote location.

The level sensors are the mercury-float type. However, pressure diaphragm sensors were used on earlier systems. The mercury-float type is the better of the two. Mercury is contained in two metal capsules (switches) that are encased in each polyurethane float. Normally, only one switch in each float is used and the contact closes when it is in the horizontal position.

The pressure-diaphragm type requires a 9-inch head to close and a 3-inch head to open. A rubber diaphragm deflects and closes the switch. These switches had problems, so ships were recommended to request an Alternation (AER) Kit Mercury Float 2-S4320-LL-HAL-218. NAVSEA recommends that all sensors be changed to the mercury-float type.

Sewage Transfer Hoses

The sewage transfer hose is used to transfer sewage from the ship's deck riser to the shore connection. The hose is 4 inches in diameter. Two types of hose are available: collapsible and noncollapsible.

The collapsible hose is the most common of the two. Public works centers (PWCs) have trucks with hose reels mounted in the truck beds. The collapsible hoses lie flat, and several hoses may be stored on a single hose reel. When the ship enters port, PWC will furnish the hose and make the connections on shore. The ship's personnel will make the connection on board the ship.

A noncollapsible hose is also available. It is a full bore hose that is wire reinforced and has a rigid body. This hose is superior to the collapsible hose in one respect-it does not kink up and restrict the flow of sewage.

Both types of hoses have cam-locking couplings with male and female end fittings. Both types of hoses are interchangeable with each other. Before any hose is disconnected, it must be flushed for 10 minutes to eliminate any sewage.

CHT System Labeling

All CHT system components are labeled and marked according to *General Specifications for Ships of the United States Navy,* NAVSEA 0902-001-5000. Piping that passes through unmanned spaces, such as tanks, voids, and cofferdams, is marked at least once in each space. Piping in machinery spaces is marked at least twice; at its point of entry and exit. The pipes should be stenciled to identify the system and the direction of flow. Valves and remote operating devices are labeled by service and position for system operating modes. The damage control classifications are to be plainly marked. Handwheel of valves in sewage piping systems are to be painted gold. (See *NSTM*, chapter 505.) The drains are marked to show the type of service, such as soil, waste, and garbage grinder drains.

Washup Facilities

Washup facilities, including a sink with hot and cold water, soap, disinfectant, and hand drying facilities are located in or near the pump room. The sink drains into the sump in the pump room. The sump is emptied by either an installed saltwater eductor or by a sump pump. The water is discharged into the CHT pump discharge line.

The pump room and deck discharge stations have a source of saltwater to wash up a sewage spill.

Further information on washup procedures and materials was provided earlier in this chapter under the heading Sanitation.

Fire Fighting

Fire-fighting equipment must be provided at or near CHT spaces in case of an emergency. The CHT tank may contain toxic and/or combustible gases which can be hazardous.

Communications

A telephone connection to the ship’s internal communication system is located in the pump room. Another is located at the continuously manned remote location where the high-level alarm is monitored. In addition, telephone communication at each deck discharge connection is required whenever the operating mode of the CHT system is changed. The X52J sound-powered phone circuit is used at these locations.

CHT SYSTEM OPERATIONAL MODES

There are three operating modes for the CHT system: at-sea, transit, and in-port. The at-sea mode is used when the ship is outside the 3-mile limit, known as the contiguous zone. In this mode, the valve alignment allows both the soil and the waste drains to be diverted directly overboard. The transit mode is used just before the sewage transfer hoses are disconnected and while the ship is underway within the 3-mile limit, known as the restricted zone. The valve alignment for the transit mode requires the soil drains to be diverted to the holding tank and the waste drains to be diverted overboard. The in-port mode is used whenever the ship is pierside. In this mode, the valve alignment diverts both the soil and the waste drains to the holding tank. The discharge piping is aligned to the deck risers where the sewage transfer hoses are connected to the ship's system and the pier's system. The pumps are set in the automatic mode to discharge the sewage off the ship to the pier. When ships are on extended cruises, the CHT system should be exercised in all modes at least once each week. This will allow you to flush the tank weekly as required and, by doing so, keep toxic gases to a minimum. You should check each mode of operation weekly. This will ensure that the valves operate smoothly and do not leak. Any leaks must be corrected immediately.

The Sewage Disposal Operational Sequencing System (SDOSS) was designed using the Engineering Operational Sequencing System (EOSS) as a guideline. The SDOSS gives step-by-step procedures for changing the valve alignment when changing the operational mode of the system. It also gives step-by-step procedures for other operations of the system, such as cleaning the tank. Refer to the foldouts of figures 17-1, 17-2, and 17-3 for the location of drains, valves, and other components as we continue the discussion on the various modes of operation.

At-Sea Mode

Once the ship is beyond the 3-mile limit, and in the area known as the contiguous zone, the CHT system may be placed in the at-sea mode by following these procedures:

1. Place the soil drain diverter valve (H) and the waste drain diverter valve (J) in the overboard discharge position. Ensure that the gagged scupper valves near the overboard discharge are open.

2. Open the pump suction valves (A) and the pump discharge valves (B).

3. Shift the pump discharge diverter valve (C) to the overboard discharge position.

4. Set the discharge pump controller selector switches to the MAN 1 position.

5. After the pumps lose suction, set both controller selector switches to the AUTO position.

6. Open the tank washdown supply valve (L) and wash the tank for 30 minutes.

7. Close the tank washdown supply valve (L).

8. Set the controller selector switches to the MAN 1 position.

9. After loss of pump suction, set the controller switches in the OFF position.

10. Close the pump suction valves (A) and the pump discharge valves (B).

11. For the strainer-type CHT system, close the inflow stop valves (G). For the comminutor-type CHT system, secure the comminutor isolationvalves (D) right after shifting the soil drain diverter valves (H) to the overboard position. For comminutor systems with the aeration system, close the air blower discharge valve (M) and secure the air blower. Or, secure the ship's service air system supply valves (N) once the tank washdown procedures have been completed and the pump has lost suction. If an air aspirator system is installed, shut down the system and secure the aspiration pump.

After you have placed the valve alignment in the at-sea mode, place the electrical components in the at-sea mode as follows:

1. De-energize the controller at the local power panel by placing the pump controller selector switches in the OFF position.

2. Place the local CHT holding tank high-level alarm cutout switch in the ON position. You can then monitor the tank level for overfilling.

3. Energize the high-level alarm circuit at the IC switchboard to continuously monitor the tank level.

4. Secure both the air blower and the comminutor power supply switches at the local power panel.

During the at-sea mode, you must flush the holding tank for 30 minutes each week, and pump it down even when the tank is not in use. Keep the pump rooms clean and dry. Make sure that the pump-room sumps are clean and pumped down. De-energize the pump-room power panels at the main switchboards.

Transit Mode

The OOD should inform the engineer officer 1 hour before the ship enters restricted waters. (Restricted waters are the waters within 3 miles of land.) The engineer officer will then have personnel in charge of the CHT system start switching the system over from the at-sea mode to the transit mode.

To change the system over to the transit mode, follow these preliminary procedures first:

1. Make sure the tanks are pumped down.

2. Check the pump-room power panels to ensure that all switches are in the OFF position, including the pump selector switches.

3. Verify that these valves are in their proper positions:

a. The pump suction valves (A) should be open.

b. The pump discharge valves (B) should be closed.

c. The tank washdown supply valve (L) should be closed.

d. The air blower discharge valve (M) should be open.

e. The ship's service air supply valves (N) should be open.

f. For strainer-type systems, the inflow stop valves (G) should be open.

4. Call main control and request that the CHT pump-room power panels be energized.

5. Check the comminutor belt tension.

6. For comminutor-type systems, once the power panels are energized, open the comminutor isolation valves (D) and start up the comminutor. Observe the comminutor to ensure that it is operating properly.

7. Notify DC central (or main control) that the CHT system is ready to be shifted to the transit mode.

The engineering officer of the watch (EOOW) will report to the OOD that the CHT system is ready to be shifted.

When the ship is 4 miles out from land, the OOD will direct the EOOW to have the CHT system shifted. The EOOW will, in turn, direct the CHT personnel to make the shift. The EOOW will also inform DC central when the shift is to be made.

When you are notified to shift the CHT system to the transit mode, follow these procedures:

1. Shift the soil drain diverter valves (H) to the CHT collection position.

2. Check the waste drain diverter valves (J) to ensure that they are still in the overboard position.

3. Inform DC central that the system is in the transit mode.

DC central will then inform the EOOW that the switch has been completed. DC central will then update the valve positions on the valve status board.

When the ship is going into anchorage, arrangements for a sewage barge will be required. The sewage barge is normally furnished by the host activity or by a civilian contract.

In-Port Mode

While the ship is entering port, the CHT system stays in the transit mode. Once the ship moors to the pier, it will need to be shifted to the in-port mode. The CHT personnel should stand by their assigned positions in the pump room and the deck discharge valves on the side of the ship that will be pierside. Phone communications are to be set up between the pump room, deck discharge valve stations, and DC central.

Once all hands concerned are at their assigned positions and phone communications are set up, these procedures should be used to shift the system to the in-port mode.

1. The deck discharge valve station and pier personnel will connect the sewage transfer hoses to the ship and the shore receiving riser. The hoses normally come from the pier to the ship. Therefore, a working party may be needed to haul the hoses on board.

2. The deck phone talker performs the following actions:

a. Verifies that the connections have been made on the ship and on the pier.

b. Notifies the pump-room personnel when the connections are made.

c. Notifies the pier personnel to stand by to receive sewage.

3. The pump-room personnel will now take the following actions:

a. Make sure that the pump suction valves (A) are open.

b. Open the pump discharge valves (B).

c. Shift the pump discharge diverter valve (C) to the deck discharge position.

d. Notify the deck discharge valve station personnel that the system is ready to commence pumping. (**NOTE:** The tank must be aerated continuously when it is in use. The report should be, "Pump room No.1 ready to commence pumping.")

4. The deck discharge valve station personnel open the deck discharge valve (F). The valve may be on the portside or the starboard side, depending on what side of the ship is pierside.

5. The pump-room personnel will now energize the system in the following manner:

a. Energize the pump controller.

b. Set the sewage pump selector switch in the AUTO position.

C. Depress the start button.

d. Notify the deck discharge valve station personnel that the pumps are running.

e. Shift the waste drain diverter valves (J) to the CHT collection position.

f. Verify that the soil drain diverter valves (H) are still in the CHT collection position.

g. When the tank has been pumped down and the pump stops, open the tank washdown supply valve (L). The tank should be washed down for 30 minutes.

h. Close the tank washdown supply valve (L) upon completion of washing down the tank. (**NOTE:** The comminutor and the aeration systems should be operated continuously while in the in-port mode. During extended in-port periods, the CHT tank is to be washed down a minimum of 30 minutes per week.)

6. The deck discharge valve and pier personnel must check their sewage transfer hose connections for leaks.

a. If a leak is discovered, the deck phone talker should order the pump-room personnel to stop pumping immediately.

b. The deck discharge valve station personnel are to ensure that the hoses are connected and supported properly to prevent the hose from rupturing.

c. All personnel should stay on station until it is evident that the system is operating properly without any leaks or possible problems.

7. The pump-room personnel will observe and verify that the pumps in the automatic mode are operating properly. Two cycles of operation are required to verify that the pumps alternated. To accomplish this, the pump-room personnel will take the following actions:

a. Open the tank washdown supply valve (L) to raise the level of the tank to be pumped down.

b. Check the pump-room fittings and components for leaks. Immediate action is required to correct any leaks discovered.

c. Pump down the pump-room sump.

d. Upon completion of these actions, stow the phones in the stowage box in a clean condition.

e. Clean the pump room and themselves. Personnel hygiene is important to protect everyone's health.

f. Notify DC central that the tank has been pumped down and that the system is in the automatic mode for that pump room.

DC central will then update the CHT system status board to show that the valves are in the in-port mode. DC central will inform the OOD, who will, in turn, inform the CDO that the CHT system is in the in-port auto mode.

The petty officer of the watch will log the time that the CHT system was shifted to the shore connection. If the sewage offload barge is alongside at anchorage, the petty officer of the watch will log the times that the pumping started and finished. The log entry is required to protect the ship in the event of a sewage spill in the vicinity by another ship. Furthermore, each ship should set its own procedures to ensure that the CHT connections at the deck discharge valve, the shore connection, and any hose connections in between are checked for leakage. These checks should be conducted at least once each hour.

If a leak goes unnoticed and releases sewage into the water, the ship will be in violation of the pollution control law. If a leak should occur topside, all of the pump selector switches should be placed in the OFF position. The system will need to be placed in the transit mode and the waste drain diverter valves (J) diverted overboard. Immediate action is required to repair the leak.

When the ship joins a nest of ships alongside a pier, the nesting procedures are used. (See fig. 17-4.) These procedures are basically the same as if the ship were to go alongside the pier by itself. The ship's force personnel will be required to rig and connect the hoses to their ship and to the

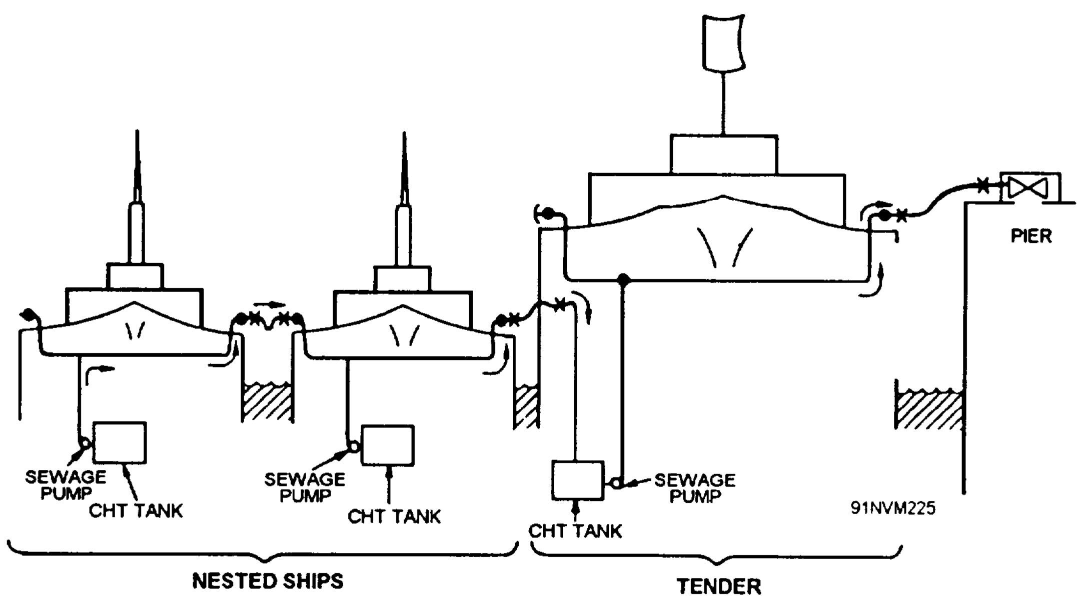


Figure 17-4.—Nested ship sewage transfer.

receiving ship. PWC, however, will normally provide the hoses. All ships in the nest must be notified before pumping. There will not be any high-level alarm conditions set on the inboard ships.

When leaving a nest, the ship follows basically the same procedures as leaving the pier. However, if your ship is inboard, all the ships outboard of yours must stop pumping and shift to the transit mode also. Once your ship has broken away, the other ships can commence reconnecting and shifting to the in-port mode.

SAFETY PRECAUTIONS FOR IN-PORT MODE.—The following precautions are applicable to operation in the in-port mode:

—In the event of a high-level alarm, you, as the operator, should recognize that a problem exists with the pumps, the discharge piping, or both. If the tank completely fills while the system malfunction is being checked out, the waste will overflow overboard and flow through any heads or fixtures located below the overflow discharge lines. These fixtures should be identified and marked before initial use of the system.

—Whenever a high-level alarm sounds, immediately close the isolation valves on the marked drains below the overflow overboard discharge and/or divert the upper deck drains overboard to prevent flooding and fouling of spaces.

—In the event of leakage or snagging of the transfer hoses, close valve (F) (see figs. 17-1 and 17-3) at the deck connection. (Closing the pier valve may cause the discharge hose to rupture.) Line up the pump discharge diverter valve (C) in the overboard discharge position to prevent overflow or backup of drains located below the tank overflow. Once the problem has been corrected, return the system to the operational alignment.

PROCEDURES FOR GETTING UNDERWAY.— When in the in-port mode, follow the following procedures to prepare the CHT system for getting underway (see figs. 17-1 and 17-3).

1. Set the waste drain diverter valve (J) to the overboard discharge position.

2. Set the sewage discharge pump controller switch to MAN 1 for emptying the tank. The aeration system should remain in operation.

3. When the discharge pump loses suction, place the controller selector switch in the OFF position.

4. Close the pump discharge valves (B).

5. Open the flushing/eductor supply valve (E) and flush the discharge piping and hose for 10 minutes.

6. Close the flushing/eductor valve (E).

7. Open the pump discharge valves (B).

8. Operate the manual hold-open device on the pump discharge check valves (K) to drain the discharge lines back into the tank.

9. Try raising the hose to remove fluid from the drooping portion.

10. Close the deck discharge valve (F) and the receiving station valve.

11. Break the highest hose connection first to ensure proper drainage of the hose. This allows air into the line and breaks any vacuum or pressure seal.

NOTE: Personnel engaged in sewage transfer hose operations must observe all applicable safety, sanitary, and hygienic practices.

12. Cap or seal the ends of the transfer hose.

13. Reset (close) the pump discharge check valves (K).

14. Wash down the deck connection area with a solution of hot water, stock detergents, and bleach.

15. Close the pump discharge valves (B).

The ship should now be prepared for transit. Follow the procedures listed in the SDOSS to switch the system from the in-port mode to the transit mode and then to the at-sea mode. This operation is basically just the opposite of going from the at-sea mode and working down to the in-port mode.

Sewage Transfer During Tender Operations

During all tender operations, sewage is transferred from the ships being serviced to receiving stations in the tender. Typical receiving stations in submarine tenders and surface ship tenders are shown in figures 17-5 and 17-6. The tender then transfers the sewage to the receiving facility.

Layouts for submarine sewage transfer hose connections differ from those of surface ships in that each submarine always uses independent hoses for direct transfer to a tender or receiving facility. That is, when nested, submarines do NOT discharge sewage through inboard ships to the receiving facility as in the case of nested surface ships.

Tenders furnish 4-inch sewage transfer hoses with quick-disconnect fittings for surface ships and 2 l/2-inch hoses with quick-disconnect fittings for submarines. In the following paragraphs, we will discuss shipboardsewage transfer procedures unique to tender operations.

TENDER RECEIVING SEWAGE FROM SURFACE SHIPS.—Before sewage can be transferred from tended ships, sewage hoses must be connected to the tender sewage-receiving station according to the procedures previously discussed. Then, open tender receiving station stop valves (R) and comminutor isolation valves (S) (see fig. 17-6). The surface ship should then be advised that transfer operations may begin.

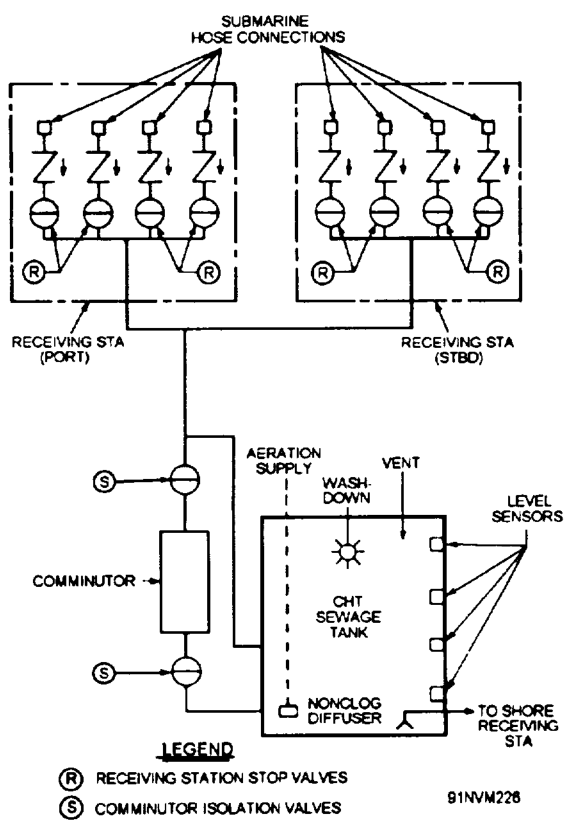


Figure 17-5.—Submarine tender receiving system.

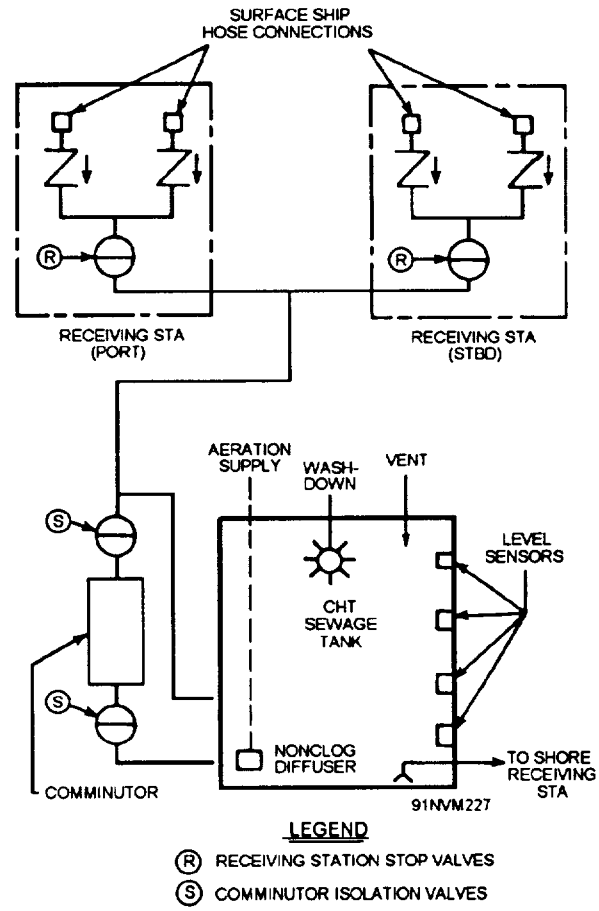


Figure 17-6.—Surface ship receiving system.

> **CAUTION**
>
> When hoses are connected during nesting operations, no valves are to be opened until after all connections are made. If the high-level alarm sounds on the tender while a tended ship's tank is being emptied, notify the ship to stop transferring, and then close the receiving station's stop valves. Investigate and take corrective action before restarting transfer operations.

SECURING TENDER RECEIVING OPERATIONS.—When the tended ship has transferred its sewage, close the tender receiving station stop valves (R), and disconnect sewage hoses from the receiving stations following previously discussed procedures.

CAUTION

Before any hose is disconnected, open all valves in the lines to the CHT tanks on the tended ships to depressurize the lines. Also assure that all pump selector switches on the tended ships are in the OFF position.

SUBMARINE SEWAGE TRANSFER TO TENDER.—Submarine transfer procedures are similar to surface ship transfer procedures. The exception is that the receiving station stop valves (R) (fig. 17-5) are opened and remain open only during receiving. Submarines must obtain permission from the tender before discharging sewage. When receiving operations have been secured, the tender gives a complete air blow of the hose and piping to minimize hose spillage during disconnect.

CAUTION

If the high-level alarm sounds on the tender while it is receiving sewage from the submarine, notify the submarine to stop transfer. Investigate and take corrective action before resuming transfer. Ensure that sewage transfer hoses are not pressurized before they are disconnected.

CHT TANK WORK PROCEDURES AND MAINTENANCE

The hygienic practices discussed under sewage transfer operations must be observed by all personnel who perform maintenance or troubleshoot the CHT system.

CHT tanks should be cleaned and inspected at least every 3 years. This inspection should be conducted only at a maintenance facility where proper industrial assistance is available. Furthermore, no work procedure or maintenance should be performed without proper equipment, safety precautions, and supervision.

Work Procedures

Advance facility arrangements should be made for a qualified gas-free engineer and for the design and installation of the necessary temporary ventilation. These arrangements should be made with the production engineering, gas-free engineering, and industrial hygiene departments, or similar operating units. Before opening the tank, these specialists should ensure that the pump room is properly ventilated and under positive pressure. The following procedures should then be followed:

1. Divert all drains overboard.

2. Isolate all heads, fountains, or drains located below the level of the overflow discharge.

3. Ensure that the valve in the overflow discharge line is open.

4. Operate the aeration system, if available.

5. Pump out the tank completely. When pump suction is lost, turn off the pump.

6. Open the tank washdown valve and fill the tank until water comes from the overflow overboard discharge. Secure the washdown system.

7. Repeat steps 5 and 6.

8. Repeat step 5.

9. Secure the air supply.

WARNING

TOXIC HAZARD: Toxic gases may exist in the tank and associated piping in and adjacent to the pump room. Do not open the system until it has been certified gas-free.

10. Have the gas-free engineer inspect the tank and issue a gas-free certificate as required in *NSTM*, chapter 074. Pay particular attention to the presence of hydrogen sulfide, methane, carbon dioxide, and oxygen. If the tank is not gas-free, reseal the tank and repeat the washdown procedure outlined previously (steps 1 through 9) until the tank can be certified gas-free and safe. The tanks must be recertified periodically. In any event, the recertification must be performed at least every 4 hours while the tank is open.

11. Even though a tank may be certified gas-free, toxic gases may remain in the sludge blanket and may be released when the blanket is disturbed. Before opening the tank in any manner (for example, by removal of manhole access covers or liquid-level sensor flanges), wear either an OBA or an air-line mask as described in *NSTM*, chapter 079, volume 4. You must have a second person on hand to lend assistance as required. A spare OBA or air-line mask (preferably OBA) must be immediately available.

12. After the tank is opened, ventilate it continuously by taking suction from the tank and exhausting directly to the atmosphere. Ventilation should provide a change of air in the tank every 3 minutes. The number and types of blowers needed, ducting path and arrangement, and position of suction in the tank are to be determined by the production engineering and industrial hygiene departments.

13. Once forced ventilation of the tank has begun (step 12), you can continue work around the tank without using OBAs or air-line masks.

14. Before entering the tank, force ventilate it for 30 minutes and then clean it thoroughly with a firehose or manually controlled high-pressure water cleaning nozzle. Continue ventilation during this washdown. Be careful not to get water into the blower inlet line or to damage internal tank equipment (level sensors). Pump out the tank as necessary during cleaning.

15. Have the gas-free engineer repeat gas level measurements. When the tank is designated gas-free and safe, you may enter using an OBA or air-line mask. Personnel entering the tank must wear overalls, boots, gloves, and head covering. If the tank is found to be unsafe, continue ventilation until it can be certified gas-free and safe. If you enter the tank alone, you must use a safety harness and tending line. If more than one person enters the tank, they should not use the tending line. However, the OBA or air-line mask wearers should keep in constant sight or touch with one another. Personnel should always be on hand outside the tank to lend assistance if required.

16. After the tank is entered, remove the remaining sludge and wash down.

17. Have the tank recertified as gas-free and safe by the gas-free engineer. If the tank is found unsafe, continue ventilation until the tank can be recertified gas-free and safe.

18. Personnel may now continue work in the tank without air-line masks or OBAs, provided ventilation is continued.

19. Inspect the tank coating, level sensors, aeration, and washdown systems. If recoating is necessary, it should be done with the four-coat tank-coating system, MIL-P-24441. The cement used to fill voids and pockets should be replaced with latex cement, MIL-D-21631.

WARNING

TOXIC/EXPLOSIVE HAZARD: The tank must be assumed to contain toxic/explosive gases until otherwise determined. Observe all NO-SMOKING regulations. Do not allow open flame, ordinary electric lights, flashlights, or sparking electrical apparatus in or near the open tank until safety is certified by

20. Do not perform any welding or hot work on the tank until the gas-free engineer first determines that the tank is safe for hot work. After the welding is completed, inspect the coating for heat damage and repair as necessary.

Toxic Gases

Toxic gases are generated at various rates depending upon the sewage temperature, pH, oxygen, and the amount of sewage in the tank. Toxic gases are likely to form in tanks where sewage is allowed to remain for long periods of time.

Therefore, the tank is to be flushed and pumped out at least weekly whether in the in-port mode or the at-sea mode.

Hydrogen sulfide (H_2S) is the most common gas you will find in the CHT system, and it can be produced within 6 to 12 hours. It can also exist as a liquid at low temperatures and high pressures. H_2S is a colorless gas that has a strong odor of rotten eggs. It can affect an individual's sense of smell and cause an irritation to the eyes, nose, and throat. A headache, dizziness, and an upset stomach are caused by inhaling low concentrations of H_2S. At higher concentrations of 1,000 to 2,000 ppm, you can go into a coma or meet sudden death after just one single breath. It is also possible that you may be completely unaware of the presence of H_2S.

H_2S is also a flammable gas. It has a lower flammable limit by volume of 4.3 percent and an upper limit of 46 percent. The au toignition temperature is 260°C (500°F). When H_2S burns, it has a pale blue flame. This type of fire may be extinguished by using either CO, or water in the fog form. The gas can travel a considerable distance to a source of ignition. Once ignited, it will flash back to the source.

The toxicity level for H_2S is currently set at 20 ppm by the Occupational Safety and Health Administration (OSHA). The National Institute for Occupational Safety and Health (NIOSH) has recommended that the permissible exposure limit be reduced to IO ppm averaged over a lo-minute period. At the time of this printing, the acceptable safe limits are set at 10 ppm averaged over an 8-hour period.

An aeration system must be provided for each CHT collection tank. The aeration system is to be operated continuously while in the in-port mode. The tank is to be pumped down each 6- to 12-hour period when in the in-port mode to reduce the amount of H_2S that may be produced.

Fresh sewage contains a mixture of bacteria, normally aerobic bacteria. The aerobic bacteria survive and grow in the presence of oxygen. If the sewage is not provided with additional oxygen (use of the aeration system), and the sewage is allowed to remain in the tank in excess of 6 to 12 hours, the bacteria will consume all the oxygen and die off. As the aerobic bacteria die off, the anaerobic bacteria begin to take over. Anaerobic bacteria require no oxygen to survive. The anaerobic bacteria produce hydrogen sulfide, methane, and other toxic and flammable gases. H_2S is not limited to the CHT system. If drainage water from refrigeration boxes gets into a confined space and is overlooked for long periods of time, it too can produce H_2S.

Other gases of concern are as follows:

—Methane (CH_4) is a colorless, odorless, nontoxic gas that is highly flammable. Flammable vapors may spread from a spill. The heat of a fire can cause a container of CH_4 to explode. Its flashpoint is -188°C and ignition temperature is 538°C. The lower flammable limit by volume is 5.53 percent.

CH_4 itself has no effect on humans. However, it does reduce the oxygen concentration of the air. If the oxygen concentration is dropped below 20 percent, an individual without an OBA, or similar device, will suffocate.

—Carbon dioxide (CO,) is primarily a colorless and odorless gas. However, CO, is also available as a liquid and as a solid. The maximum allowable dose of CO, authorized by OSHA is 5,000 ppm averaged during an 8-hour period. NIOSH has recommended that the amount be changed to 10,000 ppm averaged over a period of up to 10 hours per day. For our purposes, and keeping these figures in mind, an acceptable limit of less than 0.5 percent is authorized.

CO_2 is nonflammable, but it is an asphyxiant and a potent respiratory stimulant. It is also a stimulant and a depressant to the central nervous system. CO_2 displaces the oxygen in the compartment into which it is discharged. When you enter a space where carbon dioxide has been discharged, you must wear an approved respirator or similar breathing device.

—Hydrogen (H) is a colorless and odorless gas. It is flammable with an ignition point of 585°C and has a wide range of explosive limits. H is harmless in itself, but it can lower the amount of oxygen in the air if a leak occurs. You will suffocate if the percentage of oxygen is reduced below 20 percent.

—Ammonia (NH_3) is a colorless gas with a sharp and intensely irritating odor. It liquifies readily under pressure. It is flammable with an ignition temperature of 651°C. The flammable limits are 16 to 25 percent by volume.

NH_3 has a maximum safe level of 50 ppm. However, the acceptable safe limit is 25 ppm. Ammonia is toxic, and inhaling it in a high concentration can cause swelling of the respiratory tract. It can also cause headaches, nausea, vomiting, breathing difficulties, and coughing. If ammonia gets into your eyes, it can cause a visual disorder. If NH, gets into your eyes, wash your eyes with large quantities of water and seek medical help.

CHT TANK MAINTENANCE NOT REQUIRING TANK ENTRY

Tank maintenance sometimes calls for equipment to be removed from the outside of the tank so that an opening will be left in the tank. Some examples are the removal of level sensors, washdown nozzles, or valves adjacent to the tank and below the level of the tank overflow in the pump room. If this is done but the tank is not to be entered, observe steps 1 through 9 of the preceding discussion under Work Procedures with this exception: The ship's gas-free engineer can determine the space ventilation requirements and ensure that the atmosphere in the tank is at 10 percent or less than the lower explosive limit (LEL). Equipment can then be removed using an air-line mask or other approved respirator. Openings should then be sealed using either blank flanges or a suitable sealing device. Air-line masks or OBAs can then be removed and work can be continued on the equipment.

SUMMARY

In this chapter, you were introduced to the CHT sewage system. There are other marine sanitation devices in use. If your ship has a system that was not discussed here, refer to the manufacturer's technical manual for that system. Keep in mind that there are regulations that govern the discharge of sewage in navigable waters within 3 miles of the coastline. For your health and the safety of others, follow the prescribed sanitation procedures. Courses, PQS, and schools are available for sewage systems maintenance and operation. See your educational services officer or career counselor for more information and class convening dates for these schools.

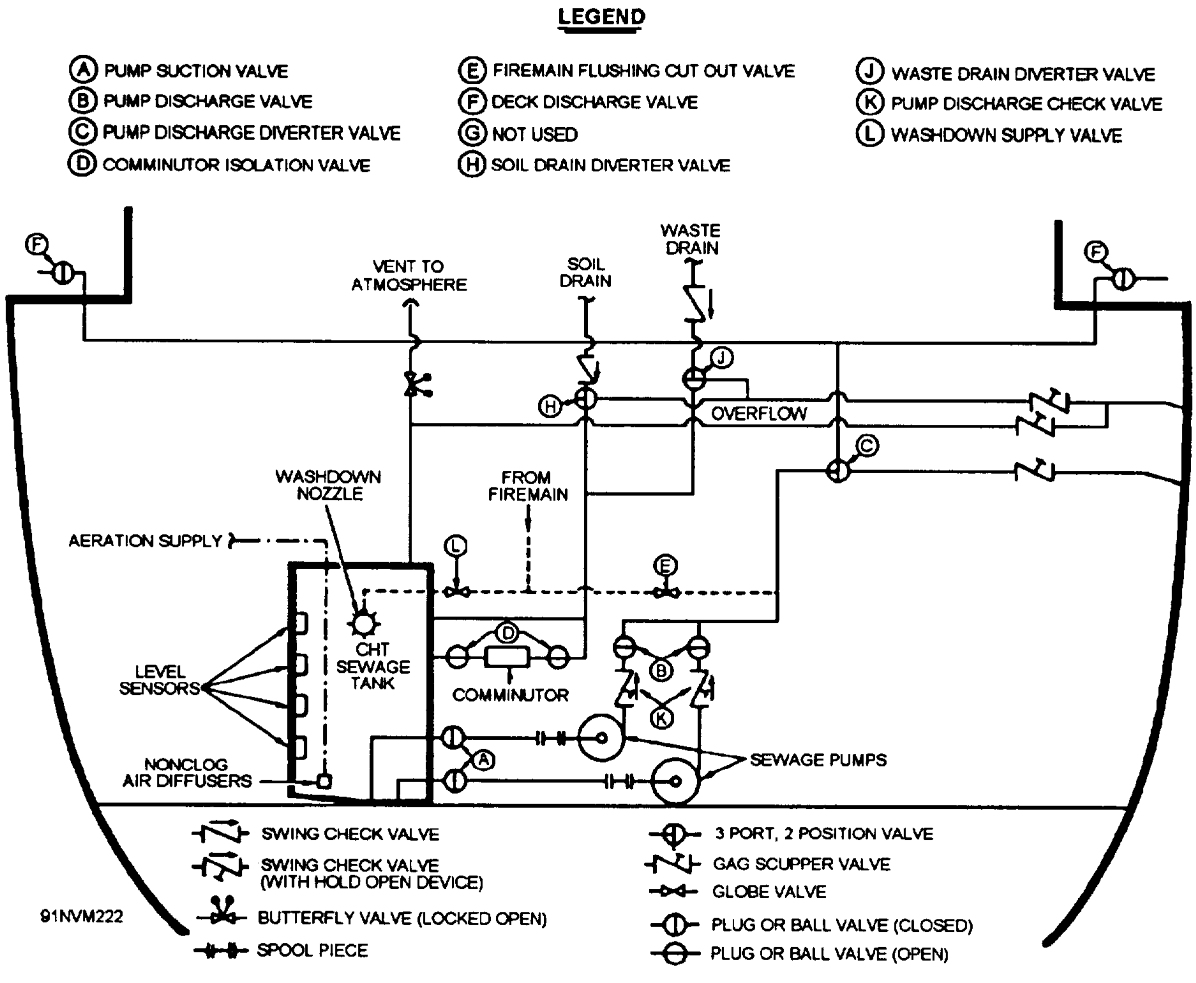


Figure 17-1.—Comminutor-type CHT system.

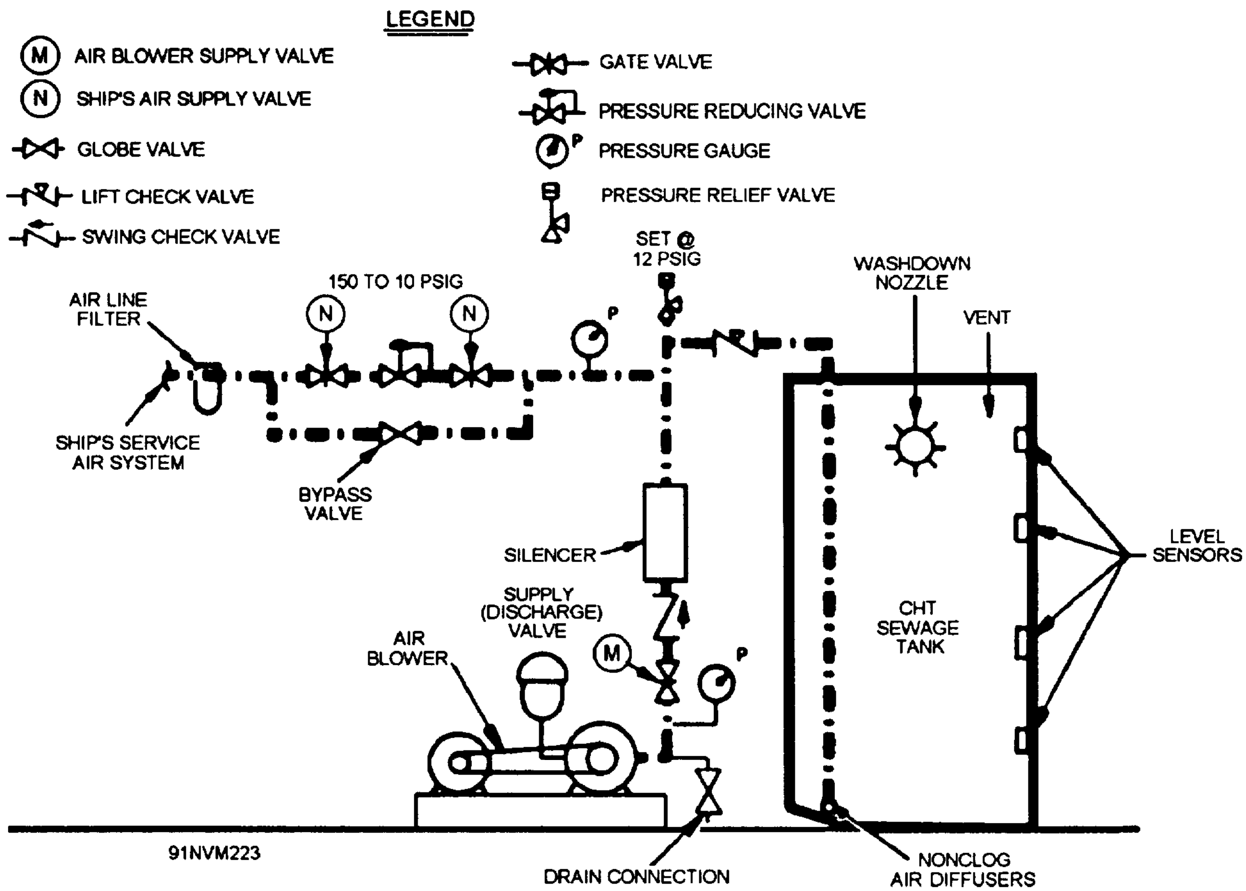


Figure 17-2.—Aeration subsystem.

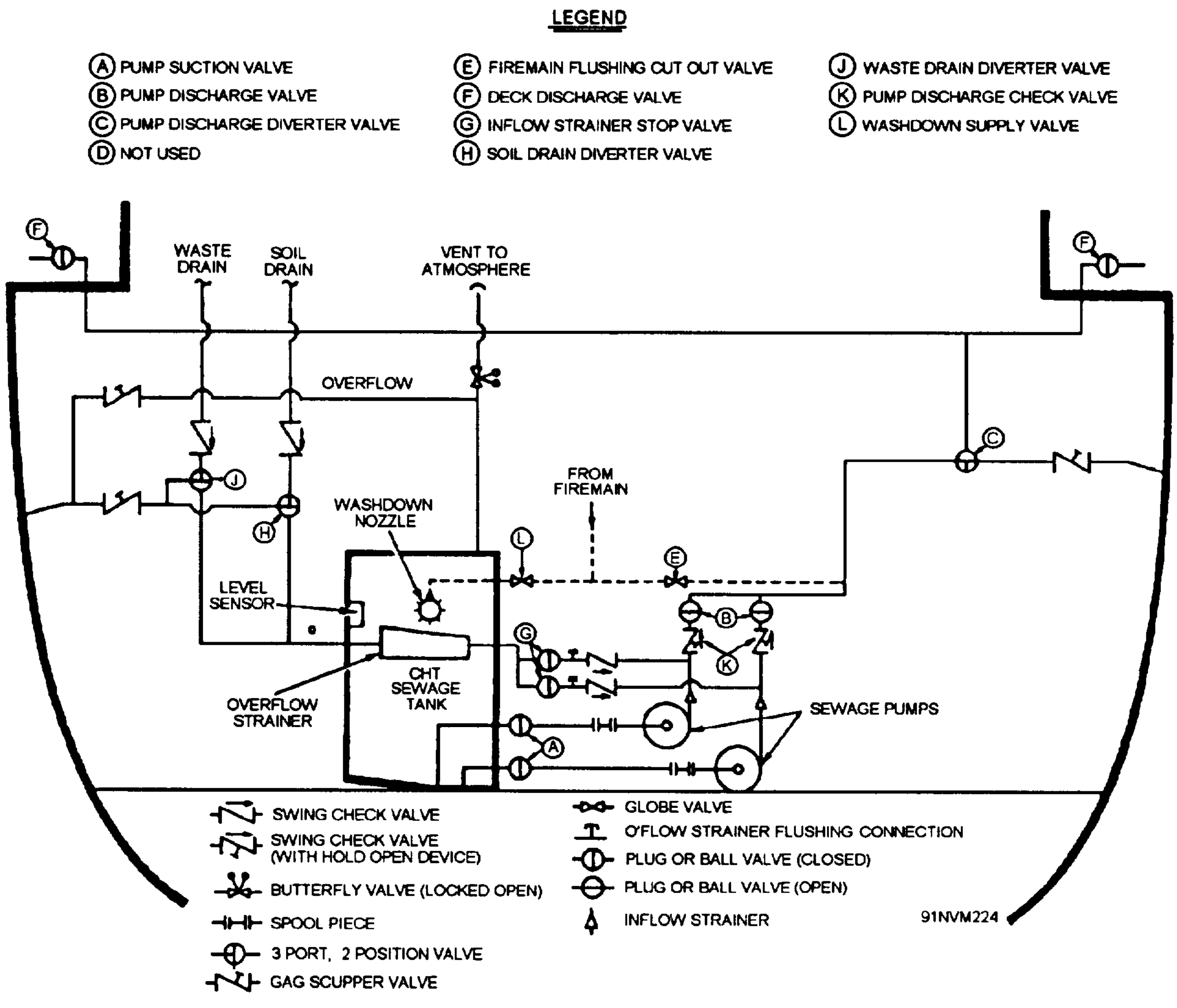


Figure 17-3.—Strainer-type CHT system.

APPENDIX II

GLOSSARY

ADAPTER— A coupling or similar device that permits fittings with different-sized openings (apertures) to be joined together.

AIR-DRIED LUMBER—Lumbered seasoned by being permitted to dry naturally.

AISI—American Iron and Steel Institute. Produces a numerical index for the classification and identification of the chemical composition of structural steel.

ALLOY—Any composite metal produced by the mixing of two or more metals.

ALLOYING—A procedure used to add elements, other than those that usually make up a metal or alloy, to change the characteristics and properties of the base metal.

ALLOYING ELEMENTS—Elements added to nonferrous and ferrous metals and alloys to change their characteristics and properties.

ANGLE VALVE—A stop valve is actually a combination valve and elbow, since its outlet branch is at right angles to its inlet branch.

ANNEALING—The softening of metal by heating and slow cooling.

ASTM—American Society for Testing Materials.

AWR—Automated Work Request. A computer-produced 3-M form that displays the information found on the 4790/2K and the planning information found on the 4790/2P and that is used by the IMA for advanced planning and work completed.

BACK-GOUGE— A term used in welding for the removal of the root and first layer of weld beads before welding the opposite side of a weld joint.

BACK-PRESSURE VALVE—A valve that is similar in design to a low-pressure valve, but which is capable of opening independently of the pressure, thereby giving free exhaust.

BACKING STRAP—A term used in welding where the root of the weld joint is closed by the application of a backer plate. This backer plate is used as a base for depositing weld metal and preventing the introduction of oxygen contamination of the root weld bead while in the molten state. The backing strap may or may not be removed after welding is complete.

BARNACLES— Small shellfish that are found attached to the bottoms of vessels and to pilings and other submerged structures.

BELL—The recessed or enlarged female end of a pipe into which the male end of the next pipe fits.

BEND—A curved length of pipe bent to a radius larger than that of an elbow. The term l/8 bend represents a 45-degree bend, l/4 represents a 90-degree bend, and l/2 represents a 180-degree bend.

BEND ALLOWANCE—An additional amount of metal used in a bend in metal fabrication.

BENDING ROLLS—A large machine used to give curvature to plates by passing them through and in contact with the three rolls.

BENDING SLAB—Heavy cast-iron blocks with square or round holes used for "dogging down." The blocks are arranged to form a large solid floor on which frames and structural members are bent and formed.

BEVEL—A term for a plane having any angle other than 90 degrees to a given reference plane. Also, a small tool similar to a try square except that the blade is adjustable for taking bevels.

BILL OF MATERIAL—A list of standard parts or materials needed to fabricate an item.

BISECT—To divide into two equal parts.

BLANK FLANGE—A flange that is complete except for drilling.

BOLT—A metal rod used as a fastening. With a few exceptions, such as drift bolts, a head or shoulder is made on one end and a screw thread to carry a nut is cut on the other.

BOLTING UP—Securing, by means of bolts and nuts, parts of a structure in proper position for permanent attachment by riveting or welding.

BONNET— A cover used to guide and enclose the tail end of a valve spindle.

BORDER LINES—Dark lines defining the inside edge of the margin on a drawing.

BOSS—A socket, with a heavy wall, that is welded or brazed onto pipe to provide connections for gauges and related fittings.

BRACKET—A steel plate, commonly of triangular shape, with a reinforcing flange on its free edges. It is used to connect two parts, such as a deck beam to a frame, or a frame to a margin plate. It is also used to stiffen or tie items, such as beam angles to bulkheads and frames to longitudinals.

BRANCH—The outlet or inlet of a fitting not in line with the axis of the system, but making an angle with it.

BRASS—An alloy composed chiefly of copper and zinc.

BRITTLENESS—That property of a material that causes it to break or snap suddenly with little or no prior sign of deformation.

BRONZE—An alloy composed chiefly of copper and tin.

BUCKLE—(l) A distortion, such as a bulge. (2) To become distorted. (3) To be bent out of its own plane.

BULKHEAD FLANGE—A flange with two bolt circles; the larger circle is to secure the flange to the bulkhead, the smaller is to secure the pipe to the flange. This type of flange is used where piping must pass through a watertight bulkhead.

BULKHEAD SLEEVE—A sleeve welded into a bulkhead with piping butted together and welded onto each end of the sleeve. If a section of pipe can be slipped through the sleeve, there is no need of butted ends inside the sleeve. However, the pipe must be welded to the sleeve at each end to make a watertight joint at the bulkhead.

BURR—The rough, uneven edge of a sheared or burned plate, or the area around a punched or burned hole. Also, a washer-shaped piece of metal through which the rivet is inserted and against which the rivet point is riveted over.

BUSHING—A hollow plug with internal and external threads, used to connect a pipe with a fitting of a different diameter.

BUTT—The end or edge of a plate or timber that comes squarely against another piece, or the joint thus formed. The long edge of a plate is called the edge and the short edge is called the end.

BUTT WELD—A welding along a seam that is not scarfed or beveled, but is joined by the edges coming together.

BYPASS—A small passage that will permit the passage of fluid in a system around a larger valve. In this way, pressure can be equalized on both sides of the larger valve so that it may be readily opened or closed as required.

BYPASS VALVE—A small pilot valve used in connection with a larger valve to equalize pressure on both sides of the disk of the larger valve before the latter is opened.

CALKING—The operation of jamming material into the contact area to make a joint watertight or oiltight.

CALKING TOOL—A blunt-ended chisel used in calking.

CAP—A fitting placed over a pipe to make a dead end.

CENTERLINES— (l) Lines that indicate the center of a circle, arc, or any symmetrical object; consisting of alternate long and short dashes evenly spaced. (2) The middle line of the ship from stem to stem as shown in any waterline view. (3) Well-defined knife or gauge lines placed upon the work to serve as a point from which dimensions will be measured.

CHAMFER—A bevel surface formed by cutting away the angle of two intersecting faces of a piece of material.

CHECK VALVE—An automatic nonreturn valve, or a valve that permits a fluid to flow in one direction but automatically closes if the fluid begins to flow in the opposite direction.

CLAMP—A metal fitting used to grip and hold wire ropes. Two or more may be used to connect two ropes in lieu of a short splice or turning in an eye. Also, a device generally operated by hand to hold two or more pieces of material together, usually called a "C" clamp.

CLEAN-OUT FITTING—One that is equipped with a cover and handhole to provide access for cleaning the pipes.

CLOSE NIPPLE—One whose length is about twice the length of a standard pipe thread and is without any shoulder.

CLOSE RETURN BEND—A short U-shaped fitting made of cast or malleable iron and used to unite two parallel pipes. It differs from the open return bend in having the arms joined.

COLD SHUT—The imperfect junction where two streams of molten metal meet but do not fuse together.

COLLAR—A threaded pipe coupling, or the sleeve in back of a riveting flange. Certain types of flanges that can be attached by peening and beading are also called collar flanges.

COMBUSTIBLE—A material that can bum, or the capability of burning.

COMMON THREAD—In machinery, an ordinary standard machine thread as distinguished from a pipe thread.

CONTRACTION—The amount that the metal will decrease in size from the time it is poured to the time the temperature has fallen to the normal temperature of the metal.

CONTRACTION RULE (ALSO CALLED SHRINKAGE RULE)—A rule having the graduations enlarged to compensate for the lessening in the size of a casting caused by the decreasing size of the cooling metal.

COUNTERSINK—(l) A tool used to chamfer the lips of a hole. (2) An operation that requires use of a countersink tool.

COUNTERSUNK—As applied to fittings, this indicates that the edges of a tapped opening are chammered to a 45-degree angle.

COUPLING—A threaded sleeve used to connect two pipes. As a joining device, it may be either straight or reducing.

CRADLE—A support of wood or metal shaped to fit the object that is stowed upon it.

CUP JOINT—A lead joint in which one pipe has a flared cup and the other pipe is tapered to fit this cup. The joint is then soldered.

CUPPING—The tendency of sawed boards to curl away from the heart of the tree.

CUTOUT VALVE—A valve that is intended normally to be fully open or fully closed.

CYLINDER—Any tank, drum, retort, receiver, or reservoir made of pipe and closed at each end, except for a required test hole.

DECK—A deck in a ship corresponds to a floor in a building. It is the plating, planking, or covering of any tier of beams above the inner bottom forming a floor either in the hull or superstructure of a ship. Decks are designated by their locations. Examples are upper deck, main deck, forward lower deck, and after superstructure deck. The after portion of a weather deck was formerly known as the quarterdeck and on warships is allotted to the use of the officers.

DECK PLATING—A term applied to the steel plating of a deck.

DEFORMATION—Permanent alteration of form or shape.

DEVELOPMENT—The process of making a flat pattern from the dimensions of a drawing. Used to fabricate sheet metal objects.

DIE—A tool for cutting threads with the cutting usually accomplished in one pass. It differs from a chasing or threading tool in that the latter has one or just a few cutting edges, whereas the die has many cutting edges.

DRIFTED—This term means that a drift or short mandrel has been passed through a pipe to remove any irregularities on the inside surface of the pipe.

DRIFT PIN—A conical-shaped pin gradually tapered from a blunt point to a diameter a little larger than the rivet holes in which it is to be used. The point is inserted in rivet holes that are not fair, and the other end is hammered until the holes are forced into line.

DRILLED—Used in connection with flanges, it means that the flange bolt holes have been made by a drill, and not by cores.

DUCTILITY—The property permitting the permanent deformation by stress or tension without rupture.

DUMMY SPOOL—A substitute piece of pipe with flanges that can be temporarily substituted for valves if the latter are not available when the piping is installed.

EDGE—An abrupt border or margin, a bounding or dividing line, the part along the boundary.

ELBOW or ELL—A fitting that makes an angle between adjacent pipes. Unless the angle is specifically stated, the elbow is a 90-degree angle.

EXPANSION JOINT—A device for connecting up long lines of pipe to permit linear expansion and contraction. The usual pattern of an expansion joint is a sleeve attached to one length of pipe and passing through a stuffing gland attached to a second length of pipe.

EXPANSION LOOP—Either a U-shaped bend or a "pigtail" coil.

EXPANSION PIPES—pipes in refrigerated spaces that lower temperature when the refrigerant flowing through the pipes changes to a gas under release of pressure, and in the process of changing from the liquid to the gaseous state, draws heat from the surrounding space.

EXTRA STRONG—The correct term for pipe that is thicker than standard pipe, but not as heavy as double extra strong pipe.

FABRICATE—To shape and assemble the component parts and to secure them in place to form a complete whole. To manufacture.

FACED—A term used to indicate that flanges are faced after they are attached to pipe, and that the pipe ends are faced flush with the flange, with flange and pipe ends at right angles to the long axis of the pipe.

FACEPLATE— A flat plate fitted perpendicular to the web and welded to the web plate; or welded or riveted to the flange or flanges of a frame, beam stiffener, or girder to balance the continuous plating attached to the opposite flange of the member.

FATIGUE—The tendency of a material to break under repeated strain.

FERROUS—Refers to metals having iron as the base metal.

FILE-FINISH—Finishing a metal surface with a file.

FILLET—A term applied to the metal filling in the bosom or concave comers where abrupt changes in direction occur in the surface of a casting, forging, or weldment.

FITTINGS—A term used to denote all bends, unions, flanges, and related parts except couplings and valves that are attached to a piping system to provide connections or outlets.

FLAMMABLE—A combustible material that bums easily, intensely, or quickly.

FLANGE—The turned edge of a plate or girder that acts to resist bending. The turned edge of a plate or shape for tying in intersecting structural members. A casting or forging attached to, or worked integrally with, a pipe to form a disk, normal to the axis of an exterior to the pipe, for connecting lengths of pipe.

FLANGED JOINT—A joint in a pipe made by bolting flanges together.

FLUX—A fusible material or gas used to dissolve or prevent the formation of oxides, nitrides, or other undesirable inclusions formed in welding and brazing. Flux also aids fusion.

FOLLOWER— A half coupling or locknut used on a long screw.

FRAME—(l) A term generally used to designate one of the transverse ribs that make up the skeleton of a ship. The frames act as stiffeners, holding the outside plating in shape and maintaining the transverse form of the ship. (2) The athwartship strength member of a ship's hull.

GAUGE—Devices for testing threaded, plug, and ringed pieces.

GAUGE LENGTH—The distance that a gauge will go on the threaded end of a pipe by hand.

GAUGE RING—A ring used for gauging the thread on a pipe.

GALVANIZING—The process by which a layer of zinc is applied to iron or steel surfaces.

GASKET—A thin sheet of composition or metal used in making a joint.

GATE VALVE—A sluice with two inclined seats between which the valve wedges down in closing. The passage through the valve is in an uninterrupted line, and when the valve is opened, the sluice is drawn up into a dome or recess, leaving an unobstructed passage the full diameter of the pipe.

GLOBE VALVE—A valve with a round, ball-like shell, and much in use for regulating or controlling the flow of gases or steam.

GRIND—Truing up the surface of a casting with an abrasive wheel or belt.

GROMMET—A ring of lampwick or hemp, soaked in red lead or linseed oil, and placed under washers. When drawn tight, this forms a watertight seal at deck, bulkhead, or shell connections.

HAND TIGHT—The effort used to hand tighten should be only that amount that the average person can continuously exert, not the forcing that could be done by a person picked for his/her strength. Standard gauges should be put on hand tight.

HARDNESS—The ability of a material to resist penetration.

HULL—(l) The framework of a vessel, together with all decks, deck houses, and the inside and outside plating or planking, but exclusive of masts, yards, rigging, and all outfit or equipment. (2) The shell, or plating, of a ship from keel to gunwale.

INCLUDED BEVEL ANGLE—A term used in the preparation of a weld joint where the total degree of bevel is determined by the addition of the bevel angles applied to both pieces of metal to be welded.

INLET—The side of a fixture in which a substance enters.

ISOTOPE—Atoms of an element having the same atomic number of different mass numbers.

JOB ORDER—An order issued by a repair activity to its own subdivision to perform a repair job in response to a work request.

JOINT, BUTT—A connection between two pieces of material that is made by bringing their ends or edges together (no overlap) and joined by welding alone, or by welding, riveting, or bolting each to a strip or strap that overlaps both pieces.

JOINT, LAPPED—A connection between two pieces of material that is made by bringing their ends together by overlapping each other and fastening, welding, riveting, or bolting the ends together.

KILN-DRIED—Lumber artificially dried in a kiln under controlled conditions.

LAYING OUT—Placing the necessary instructions on plates and shapes for shearing, planing, punching, bending, flanging, beveling, or rolling from templates made from drawings.

LAYOUT—A full-size drawing of a pattern with the appropriate shrink rule and showing pattern construction and core arrangement.

LIFT TEMPLATE—A template the same size and shape as the part of the ship involved that may be used to lay out material for fabrication.

LIFTING—The act of transferring marks and measurements from an item or model to a plate or other object by templates or other means.

MACHINABILITY—The capability of being cut, turned, sheared, and so forth, by machine tools.

MALE AND FEMALE FLANGES—The female flange of a pair has a flat, recessed face extending from inside the pipe nearly to the bolt holes. The male flange is faced with a corresponding raised portion, and a slightly smaller diameter. The object of facing the flanges in this way is to prevent a blowout of the gasket.

MALLEABLE CAST IRON—Cast iron that is heat treated or annealed so that its strength is greater than cast iron. It can be bent or hammered to a limited extent, without breaking.

MANIFOLD—A fitting with numerous branches for conveying fluids between a large pipe and several smaller pipes.

MEDIUM PRESSURE—This term applied to valves and fittings means that they are capable of withstanding a working pressure of from 125 to 175 pounds per square inch.

METALLURGY—The science dealing with the structure and properties of metals and alloys and the process by which they are obtained from ore and adapted to human use.

MIL-STD—Military standards—a formalized set of standards for supplies, equipment, and design work purchased by the United States Armed Forces.

MILL THICKNESS—Thickness of lumber as it is sawed from the log.

NIPPLE—A tubular fitting usually threaded on both ends, and not more than 12 inches long. A length greater than 12 inches is called cut pipe. A nipple is also a button or pop that is welded to the inside or outside of a pipe as a reinforcement where a hole is to be tapped.

NONFERROUS— Refers to metals not having iron as the base metal.

NORMALIZING—The act of heating iron-base alloys to approximately 100$F above the critical temperature range followed by cooling to below that range in still air at ordinary temperature.

OCCUPATIONAL STANDARDS—Requirements that are directly related to the work of each rating.

OFFSET PIPE—A pipe that is bent to move the line to a position parallel to and in alignment with the balance of the pipe. It may also be used to signify a fitting that accomplishes this purpose.

OLD MAN—A heavy bar of iron or steel bent in the form of a Z and used to hold a portable drill. One leg is bolted or clamped to the work to be drilled and the drill head is placed under the other leg, which holds the drill to its work

OPERATING GEAR—A system of rods with universal joints and couplings connecting to valves, which may be set at particular angles to fit conditions. The system extends to points above the deck and provides a means of operating the valves by remote control.

PACKING—A yielding material employed to effect a tight joint or to pack the stuffing boxes of valves. The material may be sheet rubber or braided hemp. For joints that must allow considerable or incessant motion, metallic rings are used as packing.

PAD EYE—A fitting having one or more eyes integral with a plate or base to provide ample means of securing and to distribute the strain over a wide area. The eyes may be either "worked" or "shackled". They are also known as lug pads or hoisting pads.

PEEN—(l) The lesser head of a hammer. This part is called "ball" when it is spherical, "cross" when it is in the form of a ridge at right angles to the axis of the handle, and "straight" when it is like a ridge in the plane of the handle. (2) To round off or shape an object, smoothing out burrs and rough edges.

PEENED FLANGE JOINT—A term used to indicate that the flanges are attached to the pipe by peening, rather than by screwing, riveting, or welding.

PEENING—The act or process of hammering sheet metal with the peen of a hammer, either to straighten or to impart a required curvature.

PERFORATED—A term used to describe a surface in which holes have been bored, drilled, punched, or otherwise pierced.

PERPENDICULAR—Vertical lines extending through the outlines of the hull ends and the designer's waterline.

PET COCK—A small cock used to drain a cylinder, fitting, and related parts.

PIPE—A hollow cylinder made of metal, plastic, or other materials, used for the conveyance of fluids or gases.

PIPE BEND—A bent pipe, as distinguished from a bend in a piping system where the bend is made by means of a fitting.

PIPE BENDING MACHINE—A device for coiling or bending pipe of any ductile metal. The bending is done by the use of formers and saddles. However, where the pipe wall is relatively thin, it may be necessary to use internal mandrels to prevent buckling or collapse of the pipe wall.

PIPE CLAMP—A joint support fitted with a clamp on each end, connected laterally with four short pieces of flat bar. These clamps are used for holding butt-welded and sleeve-welded joints together until they have been tacked.

PIPE COUPLING—A cylindrical sleeve or socket with female threads designed to receive the ends of two adjacent pipe lengths.

PIPE COVERING—A jacket of nonconducting material placed around the piping of a steam or other hot system to prevent the loss of heat.

PIPE CUTTER—A device for cutting pipe. The common type consists of a hook-shaped frame with a movable slide upon a stem, and another slide upon which cutting disks are mounted. As the appliance is rotated about the pipe, the cutting edges are forced into the metal.

PIPE DIE—A tool for cutting external threads on pipe. (Internal threads are cut with a tap.)

PIPE DOPE—Materials used on the threads of screwed pipe joints. There are many such compounds available under a variety of trade names.

PIPE FITTINGS—Connections, appliances, and various designs of adjuncts used in connection with pipes. Examples are elbows and bends that alter directing of flow, tees and crosses to connect branches with a main, plugs and caps to close an end, and bushings and reducers to couple pipes of different diameters.

PIPE HANGER—A suspension link or band used to support a pipe without interfering with its expansion and contraction.

PIPELINE—A run of pipe used for transporting liquids and gases.

PIPE THREAD—A thread employed in connection with pipe. The standard thread has an included angle of 60 degrees between sides, is slightly rounded at top and bottom, and is tapered. Threads may be either tapered or straight, depending upon the requirements of the specific job.

PIPE VISE—A special type of vise with three serrated jaws, one of which moves against the other two, and may be forced against the pipe by means of a screw or toggle.

PIPE WRENCH—A wrench arranged to grip with increasing pressure as force is exerted on the handle; the jaws of the wrench are usually serrated.

PIPING—The whole system of piping aboard ship. The term is also applied to a section of a system.

PITCH—Distance measured on a line parallel to the axis, and between two adjacent threads or two convolutions of a screw.

PLASTICITY—That property that enables a material to be excessively and permanently deformed without breaking.

PLUG—Without a qualifying adjective, this term is used to designate an ordinary plug or pipe plug with an exterior thread and a projecting head by which it is screwed into the opening of a fitting.

PLUG COCK—Usually called simply a cock. All cocks are essentially plug cocks.

PLUG TAP—A tap with the threaded portions straight or without lead, and designed for bottoming.

POROSITY—State of being full of pores or holes, like a sponge. A defect commonly found in weld metal.

PREHEATING—The application of heat to base metal before it is welded or cut to bring it to a minimum temperature or working temperature.

PROTECTOR—A ring threaded on its inside and used to protect the threaded end of pipe during transit.

PUNCH—A machine for punching holes in plates and shapes.

PUNCH, PRICK—A small punch used to transfer holes from a template to a plate. Also called a center punch.

PLYWOOD—A building material consisting usually of an odd number of veneers glued over each other at right angles.

PYROMETER—An instrument used to measure the temperature of metal and used in the welding process to determine preheat and interpass temperature.

RADIATOR—A coil in a steam or hot water system, or some similar device, that radiates or sends forth heat.

RADIATOR VALVE—An angle valve fitted to a steam or hot water heating radiator.

RADIUS OF BEND—The distance from the center line of a pipe or fitting to the center of curvature.

RAISED FACE FLANGE—A type of flange that has a raised face, to a height of l/l6 to l/4 inch, inside the bolt circle of the flange. The gasket is fitted to this raised portion.

REAMED—A term meaning that burrs left by the action of cutting-off tools have been removed.

REAMING—Enlarging a hole by revolving in the hole a cylindrical, slightly tapered tool with cutting edges running along its sides.

RECESSED—As applied to couplings, this term means that they are counterbored for a short distance; as applied to flanges, it means that they are provided with a calking recess at the back.

REDUCER—A fitting larger at one end than at the other, and designed to conduct flow from one size pipe to another of different diameter. Reducers have inside threading unless specified for a flange or for some special joint. The threaded type is made with abrupt reduction. The flanged type has a tapered body.

REDUCING TEE—A tee with two different sized openings. It may reduce on a branch or on the main run.

REDUCING VALVE—A spring-loaded or lever-loaded valve similar to a safety valve, designed to maintain a lower end constant pressure beyond the valve.

RETURN BEND—In general, this term signifies a fitting with inside threads that changes the direction of piping by 180 degrees.

RISER—A pipe extending vertically with side branches.

RIVET—A metal pin used to connect two or more pieces of material. The rivet is inserted into holes punched or drilled in the pieces and upset at one or both ends. The end that bears a finished shape is called the head and the end upon which some operation is performed after its insertion is called the point. Small rivets are “driven cold,” that is, without heating, and large ones are heated so that points may be formed by hammering.

RUN—A section made of more than one length of pipe; the portion of a fitting having its ends "in line," contrasted with the branch or side opening of a tee.

SAE—Society of Automotive Engineers.

SAFETY TREADS—A special nonslipping metal plate fitted to the deck at the foot of a ladder *or* stairway and often fitted on the upper surface of the steps of ladders and stairs. Steps made of safety threads are called safety steps.

SCARF—An end connection made between two pieces of material. The ends of the two pieces are tapered so that they fit together in a joint of the same breadth and depth as the pieces.

SCARF WELD—A joint made by overlapping and welding together the scarfed or beveled edges of metal plate.

SCUPPER CASTINGS—An opening cut through the waterway and bulwarks of a ship so that water falling on the deck may flow overboard. The casting is secured under the opening that is cut in the waterway.

SEAM—A term applied to an edge joint.

SEAMLESS— This term means that a pipe is without seam, especially without a welded seam. Seamless pipe is produced by a cupping or mandrel process.

SEQUENTIALLY—Done in a predesigned sequence, not necessarily in numerical order.

SET, PERMANENT—The permanent deformation caused by stressing an elastic material beyond its elastic limit.

SHEET STEEL—Flat steel weighing less than 5 pounds per square foot.

SHORT NIPPLE—A nipple with a length that is somewhat longer than the length of a close nipple, but is only a little greater than that of two threaded lengths. There is always some unthreaded shoulder between the two threads.

SHOULDER NIPPLE—A nipple that has a shoulder of pipe between the two pipe threads. This nipple may be any length, but is usually about halfway between a close nipple and a short nipple.

SLEEVE—This term is used generally to designate a tubular piece of metal that slips over a metal rod, pipe, or other tubular form.

SLIP JOINT—An inserted joint in which the end of one pipe is slipped into the flared or swaged end of an adjacent pipe.

SOCKET—A recess, or piece furnished with a recess, into which some other piece may be inserted and secured. For example, the enlarged and recessed end of a cast—iron pipe into which the end of a second pipe is inserted.

SOCKET PLUG—A device for stopping the ends of pipes or openings in pipe fittings. It differs from an ordinary plug in that it has a recess into which a wrench fits.

SOFT PATCH—A temporary plate put on over a break or hole and secured. It is made watertight with a gasket such as canvas saturated in red lead.

SOFT SOLDER—An alloy of tin and lead that melts at a lower temperature than either tin or lead.

SOLDER—An alloy used to connect two metals that are less easily heated.

SOLDER JOINT—A joint soldered by feeding solder through a hole in a valve or fitting. The piping is inserted in the valve, the connection is heated, and the solder is liquified by the heat and flows between the contacting surfaces.

SOUND—To determine the depth of water.

SPECIFICATION—A detailed description or identification relating to quality, strength, or similar performance requirements.

STANDARD PRESSURE—This term applies to all valves and fittings that support a working pressure of 125 pounds per square inch.

STIFFENER—An angle bar, T-bar, channel, or related parts used to stiffen the plating of a bulkhead or similar areas.

STRAIGHT EDGE—A relatively long piece of material having one or both edges a true plane.

STRENGTH—The ability of a material to resist strain.

STRESS RELIEVING—Heat treatment to remove stresses or casting strains.

STUD—A bolt threaded on both ends, one of which is driven into but not through a hole that has been bottom drilled and tapped, and the other end secured by the stud.

STUD BOLT—A bolt threaded on both ends, but larger than a stud, driven into a hole that has been drilled and tapped. This permits connections to the bolts on both sides of the metal while the bolt is secured in the structure.

STUFFING TUBE—A packed tube that makes a watertight fitting for a cable or small pipe passing through a bulkhead.

SWEATED—A surface coated with soft solder or tin. In making a sweated joint, the pipe and the fitting are sweated separately and then sweated again after they have been assembled.

SWIVEL JOINT—A joint that rotates about an axis without any loss in its efficiency.

SYSTEM—A grouping of components or equipment joined to serve a common purpose.

TAP—A tool used to cut internal threads. Small sizes are usually solid, but larger sizes are often made with inserted cutters so that they may be withdrawn from the work, without stopping, when the desired threads have been cut.

TEE—A fitting with a side outlet at right angles to the run; a single outlet branch pipe.

TEE BAR—A rolled or extruded structural shape having a cross section shaped like the letter *T*.

TEMPERING—The heating and controlled cooling of a metal to produce the desired hardness.

TEMPLATE—A piece of thin material used as a true-scale guide or as a model to reproduce various shapes.

TOE—The edge of a flange on a bar.

TRIANGULATION—A technique used to develop complex sheet metal forms by using geometrical constructions to translate dimensions from the drawing to the pattern.

UNDERCUT—A defect in the toe of a weld bead where the base metal is washed away by the welding process, leaving a crater.

UNITED STATES STANDARD THREAD—The standard screw thread with an inclined angle of 60 degrees between threads and one-eighth flattened at top and bottom. It is also known as Sellers Thread and Franklin Institute Standard Thread.

UNION—A term used to describe almost any device used to connect pipes. A union ordinarily consists of three pieces: thread end fitted with exterior and exterior threads, bottom end fitted with interior threads and a small exterior shoulder, and a ring with an inside flange at one end and inside threads similar to that on the exterior of the thread end on the other. A gasket is placed between the thread and bottom ends, which are then drawn together by the ring. The use of unions permits connections with a minimum disturbance of pipe positions.

VALVE—A device for regulating, stopping, or starting flow in a system, and for controlling the direction of flow.

VALVE SEAT—A flat or conical fixed surface on which a valve rests, or against which it presses.

VALVE STEM—A rod or spindle attached to a valve and used to move the valve.

VENT—A valve or pipe in a tank or compartment used to permit air to escape.

WARPING—The distortion, twisting, or bending of metal from its normal form caused by the absorption and loss of heat.

WATER HAMMER—A shock or blow on metal piping that results when flow is suddenly arrested. An example is steam condensing into water and rushed against elbows, or valves, by the force of following steam rushing into cold and partially empty pipe. The remedy is easy bends in pipe, slow admission of fluid until all piping in the system is brought to the required temperature, and slow closure of valves.

WELDED FLANGE JOINT—A joint made by flanges attached to a pipe by welding. The material of the flange must be capable of being welded. The end of the pipe is slipped through the flange ring forgings, and then the assembly is brought to welding heat and hammered or pressed together.

WELDING LEAD—The conductor through which electrical current is transmitted from the power source to the electrode holder and welding rod.

WHEEL VALVE—A stop or gate valve that can be opened by means of a handwheel and screw rather than by the lever, which is a feature of some gate valves, and of some butterfly and other throttle valves.

WIRE—The term applied to pipefitting means a template that has been bent for a piece of pipe.

WYE or Y—A fitting, cast or wrought, that has one side outlet at any angle other than 90 degrees. If no angle is specified, a Y is set at a 45-degree angle.

Y BRANCH—The same as a Y, although the term is also used at times todesignate a fitting whose shape is nearly like that of a single sweep tee.

YIELD POINT—The stress at which a piece of material under strain yields markedly, becoming permanently distorted without increase of load.

YOKE—In a rising stem valve, this is the portion of the bonnet that supports the nut or handwheel. As applied to pipe, the term indicates two branches-for example, hot and cold water uniting to form one stream.

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